Manual

4

MOBILE-AGENT SET SIMULATION

MASS

Core Manual

Core Manual

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The Devil is in the details!

Introduction

This manual focuses on the CORE of MASS., i.e., on the fraction of the code providing graphical and processing facilities to all DLLs that application developers may customize for advanced applications. For customization and application examples, see Manual 3 entitled "*DLLs Manual*", which explains how writing and adding DLLs. To learn how using MASS, see Manual 2 entitled "*Tutorial*".

This manual is manual four of MASS documentation. Its aim is twofold: First, it is a *programming tutorial* for new **CORE** programmers to quickly understand the **CORE** structure and the algorithms involved in the different modules. Reading this manual without accessing the code will be less beneficial. Second, it is the **CORE** reference documentation for programmers already involved in the development.

MASS is an integrated development environment (IDE) to study the coexistence of large populations of **agents**. Perhaps, the most interesting feature of MASS is that it is a **generic** application, allowing each application developer to modify large sections of the code to customize the simulator in relation with his own application. To achieve genericity, we chose to split the simulator code in two parts, namely the **CORE** and the **EXTENSIONS**, as described below:

- The **CORE**[(1)] is essentially an agent scheduler. Simply, recall that the progression of the simulation is nothing but the succession of action or communication cycles executed sequentially by the different agents. This mechanim is supervised by the CORE scheduler, which triggers the agent cycles as follows:

[(1)] *It is represented at runtime by the executable file* `MASS.exe`.

1. Each agent has two private times (ICT), one for its next ACTION cycle and one for its next NODE cycle. NODE cycles are executed for communicating agents only.
2. The CORE scheduler activates the agent having the lowest value of all ICTs. If this times corresponds to an ACTION, the activated agent executes an ACTION. In the other case, the agent executed a NODE cycle, i.e., a communication cycle.
3. At the end of its cycle, the activated agent increments its ICT with a time interval ΔT. Note that the agents operate fundamentally in the asynchronous mode, except when all agents have the same increment time ΔT.

Concretely, the CORE animates the coexistence of (at most) six populations of agents (each one comprising from one to several thousands of agents in the steady-state or transient regime) moving among obstacles across a 2-D plane[2, 3].

Additionnally, the **CORE** provides many facilities to display the agent dynamics, to initiate the agent populations, to calculate agent properties at runtime, etc…

- The **EXTENSIONS**, customized by application developers, include the specificity of the agent behavior. Each **EXTENSION** is represented by a DLL. Consequently, **the CORE only schedules the agent cycles and does not know how agents behave because the code controlling the behavior of agents is in the DLLs customized by application developers.** DLLs are extensively described in Manual 3 entitled: DLL Manual. Each DLL includes:

  A decision tree: As we consider a behavioral description of agents, *(as in Ref.* [1]),each agent executes its mission following a decision tree. This approach allows the modeler to capture agents and their environment as finite-state automata. This paradigm is widely used as a unifying perception throughout the literature of agents and multiagent systems.

  Action functions executed in the **ACTION cyle**. Here the agent executes a series of procedures (move, update of its internal variables, etc..) in accordance with its mission. When agent-agent communications (AAC) are enabled, the agent also decodes the messages stored in the input buffer of its node, and possibly creates messages that it stores in the output buffer of the node.

  Communication functions executed in the A **NODE cycle**. When AAC are enabled, the agent operates as a network node to remit the messages stored in its input buffer(s).

A CORE facilities

The **CORE** includes the general classes to write a Windows application. It implements the following facilities (latest revision of this section: 26 Jan 2002):

- Three display modes.
  - Mode 1 displays the terrain and traces at runtime the agent moves (see chapter 7 page 120).
  - Mode 2 displays the draft window to draw the objects (lines, rectangles, ellipses…) which enable defining any initial distribution of agents and obstacles (see chapter 6 page 100).
  - Mode 3 displays in a 2D graph any user-defined function (see chapter 5, GRAPH page 84).

[2] Adding a third dimension to consider moves in a 3D space would be easy.

[3] Extending the code to consider 10 populations of agent would be very easily due to the code scalability.

We believe that it would be dangerous to underestimate the importance of graphic capabilities and interface interactivity when studying complex systems involving thousands of interacting agents. On the contrary, they are essential for the global efficiency of any simulator dedicated to the analysis of such complex systems. Tracing the agent moves is a crucial feature to observe the behavior of large populations, to analyze the emergence of collective behaviors such as symmetries, order, metastable states irregular diffusions, or simply the evolution in an heterogeneous environment, that could not be detected otherwise. We believe that a great simulation engine in a weak interface is not more powerful than a great interface encapsulating a weak simulation engine.

- A syntax-colored editor coupled to a C-code interpreter (see chapter 4, page 72) to edit and calculate at runtime user-defined functions without code recompilation. The 2D GRAPH module plots these functions.
- Tools to save periodically at runtime WMF images of the terrain and to replay the observed evolution of the agent populations.
- Several property pages to customize the terrain, the obstacle and agent parameters, the construction and the representation of the environment, and to setup the parameters of the agent policies (see paragraph B page 63).
- The implementation of a default-application (to make sure that MASS starts even if some extensions are not found on startup), i.e., a Predator-Prey game, based on two agent classes defined as follows:
  - Agent-0 are predators. They attack agent-1 (mission 1)
  - Agent-1 are preys. They flee away from agent-0 (mission 2).

B Extensions: DLL

Each agent is attributed a mission. The **EXTENSION** includes the code to define the agent mission and the policy followed in the framework of the mission. Thus, the behavioral code of the agent is not in the **CORE** but in the **EXTENSIONS**, which are represented by dynamic linkable libraries (DLL) written by third-party programmers. Each DLL describes one (or several) policy(ies) followed by the agent to execute its mission (see Manual 3: DLL manual).

It must be stressed that the policy defined in the DLL is just a startup policy, as each agent can apply (separately) a reinforcement-learning algorithm to adapt subsequently its own policy depending on its own experience.

The policy is constructed by defining states, actions, a reward function and a table to map states and actions. This table is the agent policy (we follow Sutton & Barto's approach [2,3]). Thus, each agent resembles a finite-state automaton, except that, following each iteration, it must identify the environment state prior to choosing an action following its decision tree.

This manual is divided in 3 parts:

- Part 1 until chapter 7 page 120 describes the base classes to write a Windows application, and more generally the interface.
- Part 2, chapter 2 page 33 and chapter 8, describe the simulator principle, the agent model, i.e., the concepts of environment, states, actions, policies.. and how these concepts are implemented in C++ classes.

- Part 3 reduces to chapter 9 page 150. It describes how the CORE interacts with DLLs and calls the entry functions.

Chapter 1

Core fundamentals

This chapter outlines the application structure, the location of files. We also review the different modules., the principles of operation and the main functions executed at runtime.

All files of MASS are grouped together in a (daily-saved) directory. Fig. 1 shows this system file when the development was save in the directory entitled `Dec01_DEBUG_OK`, probably saved on Dec 1st.

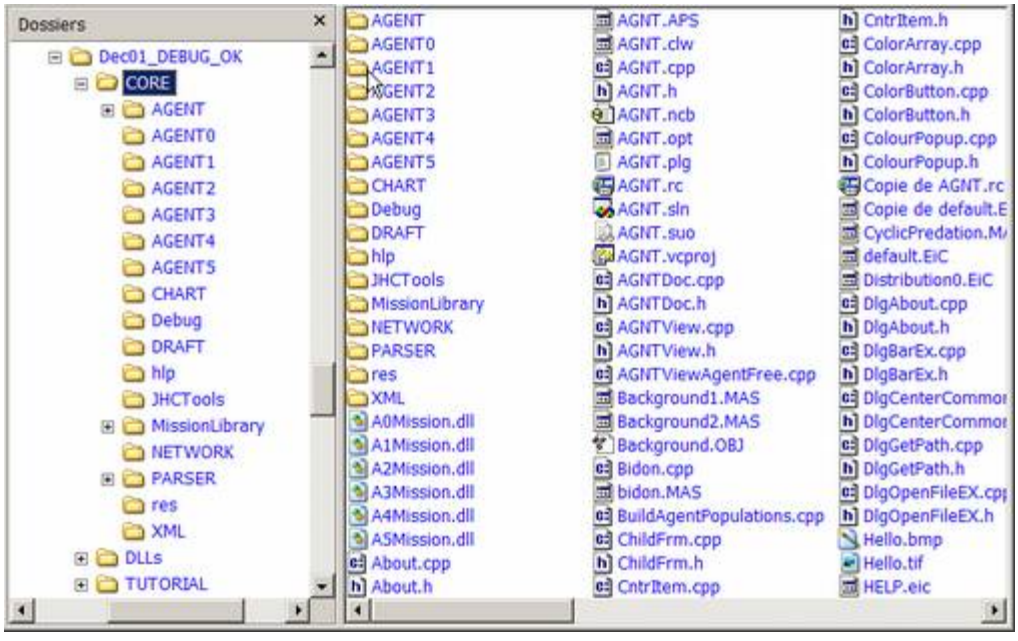


Fig. 1: The project is here sotred in the directory Dect01_DEBUG_OK. It includes the three subdirectories entitled CORE, DLLs, TUTORIAL

All files are distributed in 3 subdirectories respectively entitled **CORE**, **DLLs**, and **TUTORIAL**.

- **CORE** itself is split in 17 subdirectories (in the version 2009 of MASS). We have followed the basic principle consisting in dividing the code in quasi-independent **modules**. *Quasi-independent* means that:
  - The different modules correspond to specific and independent sets of functions of MASS.
  - The code of the different modules is stored is separate directories. Fig. 1 shows that the files in the directory CORE are distributed among several sub-directories, namely: AGENT, AGENT0, AGENT1… until AGENT5, DRAFT, GRAPH, PARSER, NETWORK, XML, etc...
  - Inter-module communications generally reduce to passing a pointer to one single function in each module, so-called *main module function*.

  This modular organization makes that a programmer can durably work to improve a module without interfering (too much) with the programmers operating in other modules.The file decoded by VisualC to manage the CORE project is `CORE\AGNT\AGNT.sln`[(4)].
- **DLLs** includes the user-defined DLL projects. The idea is to extend the application by adding the functions describing the agent behavior in DLLs customized by third-party programmers who have no access to the application CORE. The discussion on code customization and DLLs is deferred to chapter page **Erreur ! Signet non défini.** and to Manual 3 entitled DLLs Manual.
- **TUTORIAL** includes the DLL projects, which are studied in Manual 3.

A Threads & Modules

A.1 Interface thread (Thread I)

The interface thread in split in 5 modules as represented in Fig. 2. The functionalities of the different modules are the following ones:

- **WIN32** includes the files initially generated by the Visual C++ IDE to build a MFC application (i.e., the classes derived from `CWinApp`, `CmainFrame`, and the couple `Cview-Cdocument`) plus some additional files to enrich the interface (mostly classes derived from `Cdialog`, `CpropertySheet`, `Cpropertypage`, etc..). See chapter 3 page 60.
- **PARSER** is a C-like interpreter based on *EiC*. See chapter 4 page 72. EiC is a freeware written by Edmond J. Breen, available from the WEB site: `http://www.kd-dev.com`. The interpreter is embedded to customize at runtime the data plotted by the GRAPH module without recompiling the code.
- **CHART** is a tool to plot the function defined in the edition window of the interpreter. See chapter 5 page 84.
- **DRAFT** is a vectorial tool for drawing lines, rectangles, polygons… to define the initial distributions of obstacles and agents in the terrain. See chapter 6 page 100. WIN32 invokes DRAFT simply by creating an instance of the top DRAFT object, which is a window containing the user-created objects.

*(4) Following the terminology of VisualC7, all files needed to develop an application represent a **Solution**..*

- **GDI** processes all calls to build a 2-D display of the terrain and to trace the moves of the agents. It is also invoked to save to disk WMF images of the terrain. See chapter 7, page 120.
- **NETWORK** includes the classes to integrate agent-agent communications. See Manual 3 entitled DLLs Manualo.
- **XML** includes the classes to write and read scenario files from disk.

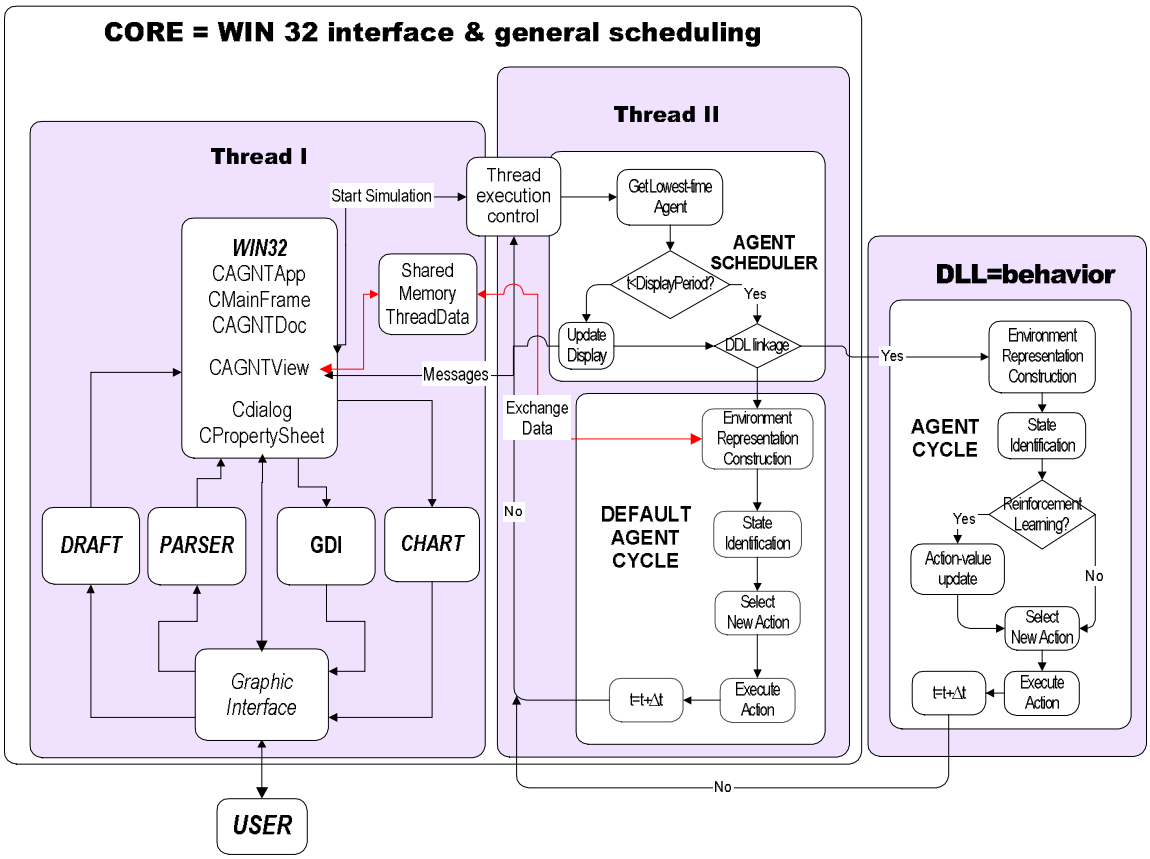


Fig. 2: **Threads and modules**: The user interacts with Win32 via PARSER, DRAFT (to customize the application parameters), GDI and GRAPH for various displays modes. All these interface modules are executed in Thread I. The population dynamics and the behavior of agents is calculated separately in Thread II. The flowchart in Thread II is a simplified version that does not include agent-agent communications.

A.2 Calculation thread (Thread II)

The **Agent cycle** (described extensively from chapter 2, page 33) is executed separately in the second thread entitled `Thread II` in Fig. 2[(5)]. Contrarily to the previous modules, it requires little knowledge of Win32 programming. It contains the routines necessary to evolve

[5] *For the sake of simplicity at this stage of the manual, Fig. 2 shows the single-thread version of the agent cycle processing. Multi-threaded processing is described in chapter 2.*

the agent populations, to build the representation of the environment of each agent, to identify states, to evolve the agent policy by reinforcement learning and to execute actions. Fig. 2 shows that the agent module is essentially composed of a scheduler, which manages the tours of agents..

A.3 DLLs

It is important to underline that the processing thread (Thread II) is **BLIND** in that the specificity of the application (so-called scenario) is exclusively integrated in the DLLs. Thread II conducts a generic processing which never considers the specificity of the DLLs. Concretely, the user selects a scenario (a file with the extension mas) and the CORE will link at runtime with external DLLs to tackle new (user-defined) missions. Practically, the user selects the DLL (one per agent class) in the directory entitle `MissionLibrary` (see Fig. 1).

B Shared Data

Perhaps, the most difficult challenge of the design when writing a large application supposed to evolve over several years is the very the first step, which consists in choosing "judiciously" how representing the data, and how processing them in the application. The initial choices are crucial as they lengthily influence the structure and the simplicity of the code. Unfortunately, the experience proves that, in the long term, any initial choice becomes always inexorably more or less unsatisfactory, simply because the application evolves and because it was impossible to comprehend from the very beginning all the constraints that will emerge in the future developments! Of course, MASS does not avoid this rule.

We chose to define a common memory space (CMS) shared by the threads Thread I and Thread II in Fig. 2**.** This shared space is represented by the structure `COREDATA` described a few lines below. Practically, the structure `COREDATA` `ThreadData` is a member structure of the class `CAGNTView`. A pointer `pData` to this structure is passed to the thread function (`ThreadFunction`) executed in **Thread II**. During the simulation phase:

- The computation thread `pThread` peaks and pokes in `ThreadData` to calculate the evolution of the agent populations.
- `pView` also peaks and pokes in `ThreadData` to update the graphic display. The update of the graphic display is triggered by `pThread` which periodically sends private `messages` that `pView` uses to *synchronously* update the graphic display through the GDI or the GRAPH modules.

The main advantage of the CMS approach is the simplicity of the **CORE**. All agent classes belong to the CORE, even if some agent methods are imported from DLLs (when the DLL linkage is selected). Each agent can easily read the terrain state and the members variables of another agent. The **CORE** programmer can simply overload functions and agent classes. The **CORE** is simple and efficient. However, there are two drawbacks:

- It is necessary to careful control the READ and WRITE operations of shared variables that can be interlaced by the operating system, leading to erratic abortion of the application. This issue is discussed below in the section C entitled *Thread synchronization.*
- This approach limits the customization of DLLs, which import the agent header from the **CORE**. Thus, a DLL programmer (i.e., an application developer) can customize the agent methods in the DLLs (without changing the call parameters), but he (she) cannot not extend the agent classes by defining additional methods that would generate different agent headers in the DLLs and in the compiled CORE! The sole solution to extend the agent classes consists

in extending the headers in the **CORE** (that is only possible for **CORE** programmers) and in recompiling the CORE and automatically all DLLs with the utility entitled `DLLCompiler.exe` described in the DLLs Manual.

We detail below the declaration of the agents, of the obstacles and of the terrain in the structure `COREDATA`:

```
struct COREDATA
{
////////////////////////////////////////////////////////////////////////////
      short iDY;                    //SHIFT
////////////////////////////////////////////////////////////////////////////
//SECTION 1: AGENTS
      AGENT*       Agent[AGENTTYPENB];
      short       iAInitNb[AGENTTYPENB];          //INITIAL NUMBER OF AGENTS
      short       iAMAXNb[AGENTTYPENB];           //MAX NUMBER OF AGENTS RESERVED IN
MEMORY
      AGENT0*       Agent0;
      AGENT1*       Agent1;
      AGENT2*       Agent2;
      AGENT3*       Agent3;
      AGENT4*       Agent4;
      AGENT5*       Agent5;
   etc,etc…
```

Script 1: Beginning of the COREDATA structure declaration

The number of different populations of agents is `AGENTTYPENB`. At the moment, `AGENTTYPENB=6` (defined in `AGENT\Global.h`), so that MASS simulates the coexistence of 6 populations of agents. Note that some agent populations can be empty (i.e., `iAMAXNB[i]=0` for population `i`) when the problem under consideration can be described with less than 6 agent populations.

`AGENT` is the base agent class. The agent populations (`AGENT0`, `AGENT1`… until `AGENT5`) are classes derived from `AGENT` (the description of the agent classes is postponed to section D.6, page 23).

```
////////////////////////////////////////////////////////////////////////////
//SECTION 2: OBSTACLE
short      iObst1Nb;              //NB OF TYPE1 OBSTACLES IN THE TERRAIN
OBSTACLE* Obstacle1;           //OBSTACLES OF TYPE1 IN THE TERRAIN

etc,etc…
```

Script 2: Fraction of the COREDATA structure declaration

Each obstacle is represented by an OBSTACLE object (the declaration of class `OBSTACLE` is in paragraph D.4, page 22). The number of obstacles is `iObst1Nb`.

```
////////////////////////////////////////////////////////////////////////////
//SECTION 3: TERRAIN
      short   XDim;          //X DIM OF THE TERRAIN
      short   YDim;          //Y DIM OF THE TERRAIN
      CELL*   Cell;          //THE TERRAIN IS A RECTANGULAR ARRAY OF CELL OBJECTS
      bool    bXtorusMode;   //if TRUE, NO X BORDER, CYCLIC CONDITION
      bool    bYtorusMode;   //if TRUE, NO Y BORDER, CYCLIC CONDITION
      short   iteratNb;      //
```

Script 3: Fraction of the COREDATA structure

The terrain is a rectangular array of `CELL` objects. The number of cells is `XDim` in the X direction (`YDim` in the Y direction). All cells are stored in a 1-dimension array of dimension `Xdim*YDim` to enable dynamic construction of the terrain at run time. The declaration of `class CELL` is shown below in Script 4:

```
class CELL (March 27, 2004)
////////////////////////////////////////////////////////////////////////////////
//      THE CELL CLASS ONLY CONTAINS THE CELL STATE AT THE MOMENT. HOWEVER, IT
//      CAN EVOLVE IN THE FUTURE (FOR INSTANCE TO INCLUDE CHEMICAL TRACES...ETC)
////////////////////////////////////////////////////////////////////////////////
{
        public:
        char State[2]; //STATES: State[0]: 'E': EMPTY; 'O': OBSTACLE;
                       //                  '1': AGENT iAType=0; '2': AGENT iAType=1
        short  iRank;    //RANK OF THE AGENT (OR OBSTACLE)IN THE CELL
        int*   iData;    //FREE INTEGER ARRAY
        int    iDataNb;  //DIMENSION OF iData
        float* fData;    //FREE FLOAT ARRAY
        int    ifDataNb; //DIMENSION OF fData
        CELL();                                    //DEFAULT CONSTRUCTOR
        ~CELL();                                   //DEFAULT DESTRUCTOR
};
```

Script 4

The variable `iRank` is the agent rank, i.e., the second index `j` of `Agent[i][j]` to identify the rank of an agent in its array . The class `CELL` could be easily extended to include explicitly additional properties such as pheromones, or any chemical trace. However, this extension would force recompiling the **CORE** and all **DLLs**. So to simplify customization, the CELL class includes two free arrays `iData` and `fData` to possibly store parameters specific to the problem under consideration.

Example: One may consider the `float` array `fData` of dimension 6 (i.e., `ifDataNb=6`), to describe two pheronoms with their lifetime and diffusion coefficient. In that case:

- `fData[0]`, `fData[1]`, `fData[2]`, are the concentration, the Lifetime and the diffusion coefficient for Pheromon1, respectively,
- `fData[3]`, `fData[4]`, `fData[5]`, are the concentration, the Lifetime and the diffusion coefficient for Pheromon2, respectively,

The benefice of the shared-memory space is that any function in the work-thread can scan (at runtime) the terrain (i.e., the array `Cell[i]`) or the agents (i.e., the elements `agent[i][j]`, where `i` is the agent type and `j` the index of the agent in the array) to retrieve the information necessary to construct the environment representtation and to decide actions. Let us consider two examples for clarity.

Example 1: Retrieving agent properties from the terrain scan

Suppose we scan the terrain. Each cell of coordinates `i` and `j` is represented by the object `Cell[i*Ydim+j]`. The cell occupation is stored in the member variable `Cell(i*Ydim+j).State`. If for instance `Cell(5*Ydim+3).State='1'`, we conclude that the cell (5,3) is occupied by an agent of type-0 (i.e., `iAType=0`). Moreover, the rank of the agent in the array `Agent[0]` is `Cell(5*Ydim+3).iRank` . Thus, we can access any member variable of this agent through the object `Agent[0][Cell(5*Ydim+3).iRank]`!

Example 2: Retrieving terrain properties from the agent scan

Suppose we scan now one population of agents, say population 1. This population is represented by the array {`Agent[1][i]|0≤i<iAMAXNb[1]`}. We can access any member variable of the agent. For instance we can retrieve the agent position (X,Y) in the terrain which is:

```
x=Agent[1][i].X
```

```
y=Agent[1][i].Y
```

It is also possible to retrieve the occupation of surrounding cells in the current iteration and in the previous iterations (see chapter 2, paragraph D.6 page 23).

C Thread synchronization

There is no memory issue so long as threads only READ shared variables. However, a dangerous conflict occurs when two threads attempt to WRITE simultaneously the same shared variable or when one thread writes a shared variable while another one is just reading it. The danger comes from the fact that READ and WRITE operations are not atomic (i.e., they can be interrupted and executed in two steps by the operating system) so that the WRITE operation can modify the data during the READ (or WRITE) operation of the other thread, leading to a READ error or to an incorrect WRITE.

In MASS, such a conflict appears if the class `AGNTView` (i.e., thread I, see Fig. 2) tries to update the graphic interface (which requires to read agent variables in `COREDATA`) when the calculation thread `pThread` (i.e., thread II, see Fig. 2) is in progress and modifies these data.

This conflict is **partly** avoided with the following communication mechanism: The calculation thread `pThread` calls the API function `SendMessage` to trigger a `CView::Paint` operation of the interface by `CAGNTView`. Now, the thread calling `SendMessage` is automatically put to sleep until `SendMessage` returns (this a property of `SendMessage`), and in this case, until `pView` has completed the graphic display. Thus, the calculation thread executes no WRITE operations while `CAGNTView` reads the shared data.

However, this protection is incomplete. It fails in particular when the user switches the display mode (using the display mode buttons of the left toolbar), forcing the painting of the interface while the calculation thread(s) is (are) in progress. Thus, we protected the next three concurrent critical functions:

```
void AGENT::UpdatePosition
void CAGNTView::OnPaint()
#include EiCExection.cpp
```

They are protected by the `Event` mechanism (i.e., a Win32 semaphore) created in the main class of MASS, i.e., in the class `AGNTApp`. This simple method consists in bracketing any critical code in specific blocks as represented in the function AnyFunction below:

```
void AnyFunction()
////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////
{
//PROTECT THE VARIABLES USED IN THE CRITICAL SECTION  AGAIN ANY CONCURENT READ OR WRITE
//OPERATION POSSIBLY SIMULTANEOUSLY ATTEMPTED BY ANOTHER THREAD,
      CAGNTApp* pApp=(CAGNTApp*) AfxGetApp();
      WaitForSingleObject(pApp->m_hSafe1,INFINITE);
////////////////////////////////////////////////////////////////////////////////
//                      CRITICAL SECTION. CODE TO PROTECT
//
                           .. .. ..  //YOUR PROTECTED CODE HERE
                           .. .. ..  //YOUR PROTECTED CODE HERE
//
////////////////////////////////////////////////////////////////////////////////
      SetEvent(pApp->m_hSafe1);      //THUS ANY CALL TO WaitForSingleObjet(m_hSafe1)
////////////////////////////////////////////////////////////////////////////////
}
```

D Cells, Terrain, Zones, Obstacles and Agents

Most parameters to build static arrays are declared in the file `global.h`.

```
////////////////////////////////////////////////////////////////////////////
#define AGENTTYPENB 6              //NB OF DIFFERENT TYPES OF AGENTS
#define CELLSTATENB AGENTTYPENB+1  //FOR OCCUPATION BY AGENTS AND OBSTACLES
#define CSTATENB 100               //NB OF CRITICAL STATES FOR STRATEGY 1
#define ITERATNB 5                 //NB OF INTERATS CONSIDERED WHEN STORING INFORMATION
#define REFLECTIONNB 10            //NB OF RELECTION ON OBSTACLES
#define MOVENB 5                   //NB OF ACTIONS THAT CAN BE CONSIDERED BY THE AGENT

#define COMPONENTNB 5  //NB OF COMPONENTS STORED TO CHARARACTERIZE THE AGENTS WHICH
                       //ARE DETECTED IN THE ENVIRONMENT. SEE THE ARRAY FoundAgent
                       //FoundAgent[i][j][k][0]: X ABSOLUTE POSITION
                       //FoundAgent[i][j][k][1]: Y ABSOLUTE POSITION
                       //FoundAgent[i][j][k][2]: Teta=Arctg(Y/X)
                       //FoundAgent[i][j][k][3]: 0 UNDEFINED;1 Target Found;2 Predator Found;
                       //FoundAgent[i][j][k][4]: INDEX OF THE AGENT, I.E, ITS POSITION
                       //                        IN THE ARRAY Agent-i (OF TYPE iAType=i)
#define COARSE 0       //USE TO DEFINE THE ENVIRONMENT MODE
#define FINE   1       //USE TO DEFINE THE ENVIRONMENT MODE
#define CHECKMODE1     //TURN ON CHECK INSTRUCTIONS. COMMENT THE LINE
                       //TO SPEED UP THE EXECUTION
#define FINEPARAMNB 10 //NUMBER OF PARAMETERS TO CHARACTERIZE THE STATE IDENTIFIED
                       //IN THE FINE ENVIRONMENT DESCRIPTION. THIS DIMENSION IS USED
                       //BY THE PARAMETER ARRAY: FINEStateParam. NOTE THAT
                       // FINEStateParam[0] IS ALWAYS THE INDEX OF THE IDENTIFIED STATE
                       //IT IS THE USER'S RESPONSABILITY TO DEFINE THE OTHER ELEMENTS
                       //FINEStateParam[1], FINEStateParam[2],...  POSSIBLE IN ACCORDANCE
                       //WITH THE DEFINITION OF THE STATE IDENTIFIED WITH FINEStateParam[0]
//WARNING WARNING WARNING WARNING WARNING WARNING WARNING
#define FREEPARAMNB 8    //NUMBER OF PARAMETERS THAT CAN BE MODIFIED BY THE PROGRAMMER
                         //IF YOU MODIFY FREEPARAMNB HERE, YOU MUST MODIFY IT IN AGNT.h
#define FREEPOLICYPARAMNB 6 //NUMBER OF PARAMETERS THAT CAN BE MODIFIED BY THE PROGRAMMER
                            //IF YOU MODIFY FREESTRATEGYPARAMNB HERE, YOU MUST MODIFY IT
                            //IN AGNT.h
#define AGENTCOLORNB 4      //NUMBER OF POSSIBLE COLOR FOR EACH AGENT
#define INTERFACEBOOLNB 10
#define PI 3.14159265359
```

The agent stores in its memory the information it recorded over `ITERATNB` activations. For instance, the last move directions are stored in the array `iSect[ITERATNB]`, where `iSect[0]` is the current value, `iSect[1]` the previous value, `iSect[2]` the value two activations ago, and so on. Past information may be used to develop non-Markovian policies.

The construction of the agent population and the simulation of moves are based on the following classes.

D.1 class CELL

A cell is an elementary square. It contains one agent or one obstacle at a time. The cell represents the ultimate spatial resolution of the simulator. Thus, the agent is anywhere in a cell. The only solution

to increase the spatial resolution consists in increasing the number of cells per surface unit. In the present version, a cell is characterized by an occupation state, which can be:

'**E**': Empty;
'**1**': Occupied by a type-1 agent;
'**2**': occupied by a type-2 agent;
….
'**6**': occupied by a type-6 agent;
'**O**': occupied by an obstacle.

The cell is represented by the following simple class.

```
class CELL
////////////////////////////////////////////////////////////////////////////
//      THE CELL CLASS ONLY CONTAINS THE CELL STATE AT THE MOMENT. HOWEVER, IT
//      CAN EVOLVE IN THE FUTURE (FOR INSTANCE TO INCLUDE CHEMICAL TRACES...ETC)
////////////////////////////////////////////////////////////////////////////
{
        public:
        char State[2];  //STATES: State[0]: 'E': EMPTY; 'O': OBSTACLE;
                        //                   '1': AGENT iAType=0;
                        //                   '2': AGENT iAType=1..  etc...
        short  iRank;   //RANK OF THE AGENT (OR OBSTACLE)IN THE CELL
        int*   iData;   //FREE INTEGER ARRAY
        int    iDataNb;  //DIMENSION OF iData
        float* fData;    //FREE FLOAT ARRAY
        int    ifDataNb; //DIMENSION OF fData
        CELL();          //DEFAULT CONSTRUCTOR
        ~CELL();         //DEFAULT DESTRUCTOR

};
```

D.2 Terrain

The terrain is a rectangular array of cells. Each cell is identified with 2 Cartesian coordinates `(i,j)`. The terrain is dynamically created with this standard C++ instruction:

Eq. 1 `CELL* Cell = new CELL [XDim*YDim];`

where `short XDim` and `short YDim` are the number of cells in the X and Y directions. Note that we define a one-dimension array `Cell[i]` to store a two-dimension table as cells are identified with two coordinates such that `0≤i<XDim` and `0≤j<YDim`. The basic reason is that C++ does enable dynamic adjustment of 2-dimension arrays. With Eq. 1, it is possible to adjust at runtime the size of the terrain in the memory[6]. The cell of coordinates `(i,j)` is located as follows in the 1-D array through the following correspondence:

cell(i,j) → `Cell[i*Ydim+j]`
Conversely:
`Cell[n]` → cell(i,j) with `i=n/Ydim` (integer division) , `j=n%YDim`

To move from cell(0,0) to cell(3,6), it is necessary for instance to move 3 times in the X direction, then 6 times in the Y direction, respectively. Note some possible redundancy. For instance:

[6] *For instance the following declaration to reserve a 2-dimension array is illegal: CELL** Cell = new CELL [XDim,YDIM].*

if `Cell[i*XDim+j].State[0]='1'`, then `Agent[0][Cell[i*XDim+j].iRank].X=i!`

D.3 class ZONE

A zone is a set of cells without any consideration to the topology of the zone. A complex zone may simultaneously contain several agents, and (or) obstacles. A zone is described by the class ZONE, which stores the numbers of contained agents and obstacles:

```
class ZONE
////////////////////////////////////////////////////////////////////////////
//  A ZONE IS A SET OF CELLS. NOTE THAT THE TOPOLOGY OF THE ZONE IS UNDEFINED.
//  CLOSE TO THE AGENT, ZONES ARE SQUARE CELLS. FAR FROM THE AGENT, A ZONE
//  IS AN ANGULAR SECTOR.
//  THE PARAMETERS THAT CHARACTERIZE A ZONE IS SIMPLY THE NUMBER OF OBJECTS
//  OF THE DIFFERENT TYPES
////////////////////////////////////////////////////////////////////////////
{
      public:
      ZONE();
      ~ZONE();

      short iRo;          //MODULUS OF THE ZONE IN POLAR-LIKE COORDINATES
      short iTeta;        //ANGLE OF THE ZONE IN POLAR-LIKE COORDINATES
      short iObstacleNb;  //NB OF OBSTACLES IN THE ZONE
      short iAgent1Nb;    //NB OF TYPE-1 AGENTS IN THE ZONE
      short iAgent2Nb;    //NB OF TYPE-2 AGENTS IN THE ZONE
};
```

Zones are used to represent the environment close to the agent. In the COARSE representation (see paragraph A.1 page 127).

D.4 class OBSTACLE

The class OBSTACLE is at the moment a simple class with two member variables that are the coordinates X and Y of the cell containing the obstacle.

```
class OBSTACLE
////////////////////////////////////////////////////////////////////////////{
      public:
//////////////////////////////////////////////////////////////////////
      short X;            //X POSITION OF THE OBSTACLE IN THE GRID
      short Y;            //Y POSITION OF THE OBSTACLE IN THE GRID
//////////////////////////////////////////////////////////////////////
      public:
      OBSTACLE();        //DEFALUT CONSTRUCTOR OF RADIUS SERIES
      ~OBSTACLE();
};
```

D.5 Terrain borders

To border the terrain with impassable barriers, we used the very efficient method that consists in filling up the cells along the borders with obstacles. Thus, the collision of an agent with the border reduces to the collision with an obstacle.

The borders may profoundly change the coexistence of the populations of agents, especially when the size of the terrain is small so that most of the agents often collide with the borders. Thus, it may be interesting in some cases to remove the borders (suppressing the generation of obstacles along the borders) and to consider **cyclic conditions** on the agent coordinates. In other words, if an agent is in the cell (i,j) and moves to the cell (i'=i+Δi , j'=+Δj), the cyclic condition defines the final position by the relations:

```
i'=(i±Δi+XDim)%XDim;   j'=(j±Δj+Ydim)%YDim
```

As a result, an agent moving outside the terrain, for instance on the right-hand side, appears on the left-hand side. Cyclic conditions are also designed as the torus mode. Note that these relations can be used even if there are obstacles along the borders.

D.6 AGENT classes

An agent is located in a cell. Its position (X,Y) is represented by the cell coordinates. It can move in any of the 8 adjacent cells as shown in Fig. 3, or in other words in the 8 directions of angle $\theta_n=n\pi/4$ (i.e., east, north-east, north, north-west, west, south-west, south, south-east). This representation must be considered as a first approach and will be improved in the future.

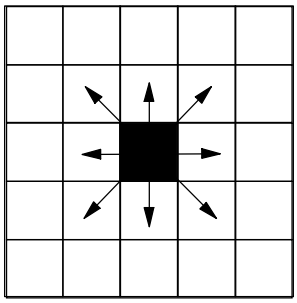


Fig. 3: Agent can move in the 8 neighboring cells

D6.1 Base class : AGENT

The header of the agent base class is shown below. It comprises 4 sections:

- Section 1 declares variables, i.e., agent attributes: the color, the XecutionTime (i.e., the reaction time, see ??), the sense radius, plus some user-defined parameters to customize the application (FreeData[FREEPARAMNB] and FreeStrategyData[FREESTRATEGYPARAMNB]).
- Section 2 declares the variables and arrays constructed in the `COARSE` representation of the environment. This representation mode is described in section A.1 page 127.
- Section 3 declares the variables and arrays constructed in the `FINE` representation of the environment. This representation mode is described in section A.2 page 131.
- Section 4 declares the directive functions (not represented). Actions and directives are described in details in chapter.Manual 3 entitled DLLs Manual.

Declaration of the member variables of the class AGENT

class AGENT (13 Feb 2004, modified September 2008)

```
////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////
{
   public:
   ////////////////////////////////////////////////////////////////////////////
```

SECTION I : GENERAL VARIABLES

```
   short X;                    //X POSITION OF THE AGENT IN THE GRID
   short Y;                    //Y POSITION OF THE AGENT IN THE GRID
   short ShiftX[ITERATNB];     //ARRAY TO STORE THE LAST X SHIFT OF THE AGENT;SHIFT
                               //PER ITERATION IS EQUIVALENT TO THE SPEED!!!
   short ShiftY[ITERATNB];     //ARRAY TO STORE THE LAST Y SHIF OF THE AGENT
   short iSect[ITERATNB];      //iSect=0=MOVE EAST;iSect=1=MOVE NORTHEAST;iSect=2=
                               //MOVENORTH;iSect=3=MOVE NORTHWEST;iSect=4=MOVE WEST;
                               //iSect=5=MOVE SOUTHWEST; iSect=6=MOVE SOUTH; iSect=7:
                               //MOVE SOUTHEAST;
   short iAType;               //TYPE OF THE AGENT:  0<=iAType<AGENTTYPENB
   short iRank;                //RANK OF THE AGENT IN ITS POPULATION ARRAY
   char  AgentMode;            //AGENT MODE; VALUES: "A" ACTIVE; "I":INACTIVE; "D":DEAD
   float DActionTime;          //TIME INCREMENT TO THE NEXT ACTION TIME
   float ActionTime[ITERATNB]; //ARRAY OF ACTION TIMES
   short iPolicy;              //POLICY INDEX
   int   ColorMode;            //CURRENT AGENT COLOR MODE (0<=ColorMode<AGENTCOLORNB)
   BOOL  bMissionDLL;          //IF TRUE, USE AN EXTERNAL MISSION DLL
   double exponent[AGENTTYPENB];//EXPONENT FOR REPULSION LAW
   int   iACTIONCycleNb;       //COUNTER FOR THE NB OF EXECUTED CYCLES
   int   iNODECycleNb;         //COUNTER FOR THE NB OF EXECUTED CYCLES
   int   iACTIONFastFullNb;    //COUNTER TO ALTERNATE FAST & FULL SCANS IN THE ACTION MODE
   int   iNODEFastFullNb;      //COUNTER TO ALTERNATE FAST & FULL SCANS IN THE NODE MODE
   float Energy;               //AGENT ENERGY
   short* Radius;              //ARRAY OF RADIUSES DEFINED AROUND THE AGENT
   short iRadiusNb;            //NB OF RADIUSES DEFINED AROUND THE AGENT
   short iSectorNb;            //NB OF ANGULAR SECTORS DEFINED FAR FROM THE AGENT
   HMODULE DLLhm;              //HANDLE OF DLL FOR DYNAMIC LINKING
   HWND  ViewHWND;             //THE AGENT CAN SEND MESSAGES TO THE VIEW. IMPORTANT
   ////////////////////////////////////////////////////////////////////////////
   short iEnvironmentMode;     //0: COARSE MODE, 1: FINE MODE
   BOOL  bIncremental;         //TRUE: INCREMENTAL CONSTRUCTION OF THE ENVIRONEMNT
   int   SenseAngle;           //SENSE ANGLE OF THE ANGLE (360 MEANS ISOTROPIC SENSE)
   BOOL  bXtendAngle;          //TO DECIDE TO EXTEND THE SENSE ANGLE
   ////////////////////////////////////////////////////////////////////////////
    ////////////////////////////////////////////////////////////////////////////
```

SECTION II : FREE ARRAY FOR AGENT CUSTOMIZATION

```
   float FreeData[FREEPARAMNB];             //FREE DATA FOR AGENT
   float FreePolicyData[FREEPOLICYPARAMNB]; //FREE PARAM FOR AGENT STRATEGY
   //FREE INTERNAL PARAMETERS THAT CAN BE USED IN THE DEVELOPMENT PHASE
   float Free[FREEPARAMNB];                 //FREE DATA FOR AGENT CODE
   int       iFree[FREEPARAMNB];                //FREE DATA FOR AGENT CODE
   bool  bFree[FREEPARAMNB];                //FREE DATA FOR AGENT CODE
   //FREE AGENT MEMORY
   short* iFreeMem[FREEMEMORYNB];           //FREE ARRAY FOR AGENT MEMORY
   float* fFreeMem[FREEMEMORYNB];           //FREE ARRAY FOR AGENT MEMORY
   BOOL*  bFreeMem[FREEMEMORYNB];           //FREE ARRAY FOR AGENT MEMORY
   ////////////////////////////////////////////////////////////////////////////
   bool bCountDown;                //bool VARIABLE TO AVOID CLOSED LOOPS
   int  iCountDown;                //int VARIABLE TO AVOID CLOSED LOOPS
   int  iSameDirection;            //int VARIABLE TO AVOID CLOSED LOOPS
   ////////////////////////////////////////////////////////////////////////////
   //OPEN ARRAYS
```

```
double Efficiency[ITERATNB];    //ARRAY OF AGENT EFFICIENT
////////////////////////////////////////////////////////////////////////////////
```

SECTION III : VARIABLES FOR CLOSED CYCLES DETECTION

```
bool bClosedCycle;              //true IF THE AGENT IS IN A CLOSED CYCLE
int ReflectPtX[REFLECTIONNB];   //ARRAY OF X COORDINATE OF REFLECTION POINTS
int ReflectPtY[REFLECTIONNB];   //ARRAY OF Y COORDINATE OF REFLECTION POINTS
////////////////////////////////////////////////////////////////////////////////
```

SECTION IV : COARSE ENVIRONMENT MODE

```
//THE AGENT STORES UP T0 ITERATNB ESTATEs THAT REPRESENT ITS KNOWLEGDE
COARSE_ENVIRONMENT COARSEEnviron[ITERATNB];//ARRAY OF ENVIRONMENT REPRESENTATIONS
                                //STORABLE IN THE MEMORY. AN ENVIRONMENT
                                //INCLUDES THE ARRAY OF FILLED ZONES AROUND THE AGENT
short StateIndex;               //INDEX OF THE IDENTIFIED STATE
short iZoneToAttack;            //INDEX OF THE ZONE TO ATTACK
////////////////////////////////////////////////////////////////////////////////
```

SECTION V : AGENT MEMORY ARRAYS IN THE FINE ENVIRONMENT MODE

```
//THE AGENT STORES STORES INFORMATION ON THE AGENTS DETECTED
//AROUND THE AGENT AT DIFFERENT SUCCESSIVE ITERATIONS. THE NUMBER OF CONSIDERED
//ITERATIONS IS "ITERATNB" DEFINED IN Global.h
short (*FoundAgent[AGENTTYPENB][ITERATNB])[COMPONENTNB];
short iDimA[AGENTTYPENB][ITERATNB];
short iFoundANb[AGENTTYPENB][ITERATNB];
short (*FoundObstacle[ITERATNB])[COMPONENTNB];//
short iDimOb[ITERATNB];         //
short iFoundObstNb[ITERATNB];   //NUMBER OF FOUND OBSTACLES STORED IN FoundObstacle
short (*COPY)[COMPONENTNB];     //COPY POINTER FOR TEMPORARY STORAGE OF THE OTHER
                                //POINTERS DURING CYCLIC PERMUTATIONS; WARNING:
                                //IT MUST NOT BE DIMENSIONNED WITH A new OPERATORS
                                //AS IT WOULD GENERATE A MEMORY LEAK!!!!!!!!!!
int iFastToFullScanRatioA;      //iFastToFullScanRatioA=3 MEANS 3 FAST SCANS FOR ONE
                                //FULL SCAN IN ACTION CYCLE (LAST LETTER A FOR ACTION)
int iScanTypeA;                 //0=FULL SCAN; 1=FAST MODE AROUND AGENTS, ETC (LAST
                                //LETTER IS "A" FOR ACTION CYCLE
////////////////////////////////////////////////////////////////////////////////
```

SECTION VI : VARIABLES & METHODS FOR COMMUNICATION

```
//THE AGENT INCLUDES AN INSTANCE OF THE CLASS NODE, AN OBJECT WITH:
//  - SEVERAL MESSAGE BUFFERS TO STORE THE INCOMING AND OUTCOMING MESSAGES TRANSMITTED
//    BY THE NETWORK
//      - AN ARRAY TO STORE THE NODES FOUND BY THE AGENT. NOTE THAT NODES ARE AGENTS FOUND
//        INSIDE THE COMMUNICATION RADIUS. THEREFORE, THIS ARRAY IS LARGER THAT THE ARRAY
//    FoundAgent, WHICH CORRESPONDS TO DIRECT SENSING OF THE ENVIRONMENT
NODE* pNode;
//THE SOLUTION TO DISACTIVATE A MESSAGE IN THE MESSAGE ARRAYS BELOW CONSISTS IN SETTING
//THE MESSAGE TYPE Msg[i].m_iType TO ZERO.
MESSAGE* OutMsg;                //ARRAY TO STORE THE MESSAGES EMITTED BY THE AGENT
int             iOutMsgSize;            //DIMENSION OF OutMsg
MESSAGE* InMsg;                 //ARRAY TO STORE THE MESSAGES RECEIVED BY THE AGENT
int             iInMsgSize;             //DIMENSION OF InMsg
//ARRAY TO STORE THE NODES FOUND BY THE AGENT WHEN SCANNING ITS COMMUNICATION DISK
short (*FoundNode[AGENTTYPENB][ITERATNB])[COMPONENTNB2];
short iDimNode[AGENTTYPENB][ITERATNB];
short iFoundNodeNb[AGENTTYPENB][ITERATNB];
int   iCOMMode;                 //0=AD HOC; 1= FULLY INTERCONNECTED, ETC...
ROUTE Route;
float ReEmitTime;       //ELAPSED TIME TO DECIDE THE REEMISSION OF A MSG
int   iMaxEmitNb;       //MAXIMUM NB OF REEMISSIONS.
int iFastToFullScanRatioN;  //iFastToFullScanRatioN=3 MEANS 3 FAST SCANS FOR ONE
                            //FULL SCAN IN ACTION CYCLE (LAST LETTER N FOR NODE)
int iScanTypeN;             //0=FULL SCAN; 1=FAST MODE AROUND AGENTS, ETC (LAST
                            //LETTER IS "N" FOR NODE CYCLE)
void BuildpMsg(int iTargetType,int iTargetRank,int MsgType,int iMsgSet, MESSAGE* pMsg);
void SendMsg(int iTargetType,int iTargetRank,int MsgType,int iMsgSet,int iOutBuf);
void SendMsg(int iTargetType,int iTargetRank,int MsgType,int iMsgSet,int iOutBuf,
```

```
            int iMsgRank,int iMaxReemitNb,int *pRoute,int data_size,int* pData,
            void* pLoad=NULL);

void DecodeMsg(MESSAGE* pMsg);
void DecodeMsgInLocalOutBuffer();
//MEMBER FUNCTION TO STORE NODES IN FoundNode
void FINEStoreNodeInArray(short iType,short iTCell,short jTCell, short Index,
                          bool bXtorus, bool bYtorus, short XDim, short YDim);
//SCAN THE CELLS OF THE ENVIRONMENT IN THE FINE MODE FOR NETWORK OPERATION
__declspec(dllexport)
      void ScanFINECellNode(CELL* Cell,short XDim,short YDim,
                  AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                  OBSTACLE* Obstacle, short iObstacleNb,
                  bool bXTorus, bool bYTorus,
                  short MaxRadius,short MinRadius);
////////////////////////////////////////////////////////////////////////////////
SECTION VII : VARIABLES & METHODS FOR REINFORCMENT LEARNING
APOLICY APolicy;        //AGENT POLICY
int            iLearnMode;     //iLearnMode<0 MEANS NO LEARNING
int            iRewardMode;    //TO SELECT A METHOD TO CALCULATE THE REWARD
int            iPreviousState; //STATE IDENTIFIED AT PRECEEDING AGENT ACTIVATION
int            iPreviousAction;//ACTION SELECTED AT PRECEEDING AGENT ACTIVATION
float   Reward();       //Reward FUNCTION CALCUATED PRIOR TO CHOOSING AN ACTION
int     SelectAction(int iStateIndex);
float   DLLReward();    //Reward FUNCTION CALCULATED PRIOR TO CHOOSING AN ACTION
int     DLLSelectAction(int iStateIndex);
////////////////////////////////////////////////////////////////////////////////
```

D6.2 Derived agent classes

In the current version, MASS comprises six types of agents derived from the base classe `AGENT`. The different types are named `AGENT0`, `AGENT1`, etc... The header of the class `AGENT0` is shown below (the headers of `AGENT1`, `AGENT2`, etc.. are similar):

```
class AGENT0 : public AGENT
////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////
{
      public:
      ////////////////////////////////////////////////////////////////
      //AGENT SCAN (FINE MODE)
      void FINEAgentScan(CELL*,short,short,AGENT* Agent[AGENTTYPENB],
                         short iAgentNb[AGENTTYPENB],OBSTACLE*,short,bool,bool);
      void FINEAgentFindState_0(CELL* Cell,short XDim,short YDim,bool,bool);
      void FINEAgentZoneScan_0(CELL*,short,short,AGENT* Agent[AGENTTYPENB],
                               short iAgentNb[AGENTTYPENB],OBSTACLE*,short,bool,bool);
      ////////////////////////////////////////////////////////////////
     //CELL SCAN (FINE MODE)
      void FINECellScan(CELL* Cell,short XDim,short YDim,AGENT* Agent[AGENTTYPENB],
                  short iAgentNb[AGENTTYPENB],OBSTACLE*,short,bool,bool,short,short);
      bool FINECellCloseScan_0(CELL*,short,short,bool,bool);
      bool FINECellRingScan_0(CELL*,short,short,AGENT* Agent[AGENTTYPENB],
                              short iAgentNb[AGENTTYPENB],short,bool,bool);
      void FINECellFindState_0(CELL* Cell,short XDim,short YDim);
      void FINEMapDirective_0(ACTION* Action,CELL* Cell, short XDim, short YDim);
      ////////////////////////////////////////////////////////////////
      //FUNCTIONS FOR CALL TO EXTERNAL DLL
      __declspec(dllexport)
      void XFINECellScan(CELL* Cell,short XDim,short YDim,AGENT* Agent[AGENTTYPENB],
                  short iAgentNb[AGENTTYPENB],OBSTACLE*,short,bool,bool,short,short);
      __declspec(dllexport)
```

```
      void XFINESelectAction(ACTION* Action,CELL* Cell, short XDim, short YDim);

      ////////////////////////////////////////////////////////////////
      //CELL SCAN (COARSE MODE)
      void COARSECellScan(CELL*,short,short,
                     AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                     OBSTACLE*, short,bool,bool,short (*LookUpTable)[2],short,short);
      bool COARSECellCloseScan_0(CELL*,short,short,ZONE*,short,bool, bool, short*);
      bool COARSECellRingScan_0(CELL* Cell, short XDim, short YDim,
                          ZONE* zone, short (*LookUpTable)[2], short iLineLength,
                          short* iFoundNb,short iDistInit, bool bXtorus, bool btorus);
};
```

The division of the agent methods between the base and the derived classes must be clear:

- The base class includes directive and action functions, which are shared by all derived classes.
- Each derived class includes member functions to construct the environment representation (`FINECellCloseScan_0`, `FINECellRingScan_0`), to identify the environment state (`FINECellFindState_0`), and to map states to directives (`FINEMapDirective_0`), in accordance with the agent specificity and the agent mission.

Some programming considerations are crucial. The code constructs several arrays of derived classes, one per agent type in the methods `void ReBuildAgentPopulation0()`, `void ReBuildAgentPopulation1()`, etc of the class `CParamSheet`. The code for the derived class Agent0 is displayed below in Script. 1.

```
////////////////////////////////////////////////////////////////////////
      i=0;      //AGENT TYPE 0, CONSTRUCTION AND INITIALIZATION
      AGENT0* Agent0 = new AGENT0[ThreadData.iAMAXNb[i]];
      for (j=0;j<ThreadData.iAMAXNb[i];j++)
      {
            ThreadData.Agent0[j].Build(ThreadData.Radius[i],  //RADIUS ARRAY
            etc…
      }
////////////////////////////////////////////////////////////////////////
      AGENT*      Agent[AGENTTYPENB];
      ThreadData.Agent[0]=ThreadData.Agent0;          //CRUCIAL
////////////////////////////////////////////////////////////////////////
```

Script. 1

Note particularly the last line, which assigns the pointer `Agent[0]` to the pointer `Agent0`, so that the array **`Agent[iType][iRank]` is a 2-dimension array to systematically access any agent of the derived classes. The functions `FINEAgentScan`, `FINECellScan`, `COARSECellScan` (see the header of AGENT0) are declared virtual in the base class so that they are automatically executed by the derived class when an agent is called via** `Agent[iType][iRank]`.

E Startup operations

It is assumed here that you previously read the second manual of the documention entitled Tutorial (i.e., the file `Tutorial.pdf`) and that you are familiar with the operation of `MASS`. Running `MASS` launches the **CORE**, which executes the start initialization that we describe below.

E.1 Default initialization

At startup, the **CORE** executes the function calls display in Script 5 below. These actions are transparent for the user. All these functions are executed to initialize (before any simulation) all arrays from default data read in files or in registries. For instance, `LoadMissionDLLs`, `LoadLibrary`… are called by `OnInitialUpdate`. At the end of this initialization phase, the **CORE** stays pending until the user selects a scenario. The initialization comprises:

- The construction of the agent and obstacle arrays.
- The definition of the agent missions and strategies from the mission scripts (see Manual 3 entitled DLLs Manual), and from data stored in the registry base of Windows.
- The construction of the learning engine, if learning is activated.

```
CAGNTView::CAGNTView
CAGNTView::OnInitialUpdate
   CAGNTView::LoadMissionDLLs
   LoadLibrary
   UpdateInterfaceFromDLL
   CAGNTView::ReadDataInRegistries
   CAGNTView::ReadDefaultDataInCore
   CAGNTView::BuildAgentPopulations
```

Script 5: Call graph during the initialization phase

E.2 Scenario loading

Following the default initialization described in section E.1, you must load a scenario prior to running any simulation. All scenarios are stored in XML files with the extension MAS. There are 2 methods to load a scenario:

Method 1: Run MASS, then click the "File" item of the menu, and select a recent file in the dialog box splashed by these actions. This procedure directly displays in MASS the intial distributions of the selected scenario. The following function calls are executed in this case.

```
CAGNTApp::OnOpenRecentFile   (Event function when you click a scenario)
          XMLNode::openFileHelper
          CView::ReadAgentFromXML
          CView::LoadMissionDLLFromScenario
          CView::ReadAgentFromXML                    SECOND CALL!
          CView::ReadPlaygroundFromXML
          CView::ReadChartParamFromXML
          CView::CreateDraftWnd()
          CView::CXDraft::ReadXMLFromDisk_2D
                 CLine::Fill
```

```
CRect::GetAbsCoordinates
CRect::FillInside
CRect::FillBorder
        CEllipse::FillInterior
        CEllipse::FillBorder
CPolyLine::Fill
CBackground::FillOusideObjects_2D
        CBackground::AreEnoughCells_2DR
                CBackground::IsCellInObjects_2DR
        CBackground::IsCellInObjects_2DR
        IsObstacleInCellR
```

Script 6: Call graph when loading a scenario using method 1

Method 2: Run MASS, then click the Open file Icon in the left toolbar ( ). This procedure displays the scenario selection box just below.

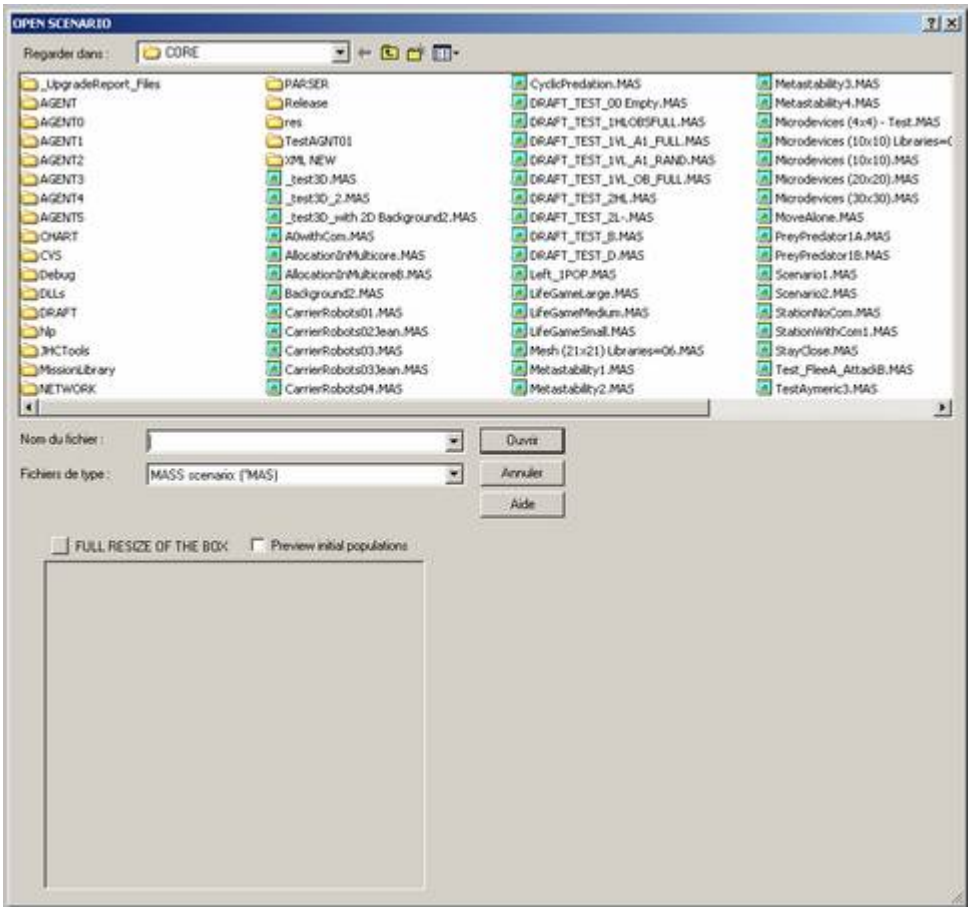


Fig. 4: Scenario selection box

Then select a scenario and click the Open button. These actions close the above selection box and trigger the new function call:

```
CAGNTDoc::OnFileOpen                          //(Event function when you click Open)
  XMLNode::openFileHelper(szFileName,"MASS")
  CAGNTView::ReadAgentFromXML                 //AGENT PARAMS: REACTION TIME, DLL NAME… (CALL1)
```

```
CAGNTView::LoadMissionDLLFromScenario
CAGNTView::ReadAgentFromXML(&InXML)      //AGENT PARAMS: REACTION TIME, DLL NAME… (CALL2)
CAGNTView::ReadPlaygroundFromXML          //PLAYGROUND PARAMS: XDIM, YDIM, TORUS MODE,…
CAGNTView::ReadSimulationParamFromXML     //SIMULATION PARAMS: NB OF ITERATIONS, SYNCHRONICITY, EiC..
CAGNTView::ReadChartParamFromXML          //
 if(pView->ThreadData.ZDim == 1) {
    CAGNTView::CXDraft::ReadXMLFromDisk(szFileName) //DEFINITION OF INITIAL DISTRIBUTION OF
                                                    //AGENTS AND OBSTACLES
            CLine::Fill
                    CLine::FillFull
                    CLine::FillEquallySpaced
                    CLine::FillRandom
              CRectangle::FillInside
                    CRectangle::FillInsideSquareLattice
                    CRectangle::FillInsideRandom
              CRectangle::FillBorder
                    CREctangle::FillBorderRandom
                    CREctangle::FillBorderFull
              CEllipse::FillInterior
              CEllipse::FillBorder
              CPolyLine::Fill
                    CPolyLine::FillFull
                    CPolyLine::FillEquallySpaced
                    CPolyLine::FillRandom
              CBackground::FillOusideObjects
else { if(pView->ThreadData.ZDim > 1)
     CAGNTView::CXDraft:: ReadXMLFromDisk_3D(szFileName)
 }
 CParamSheet::FullInitialize      //TO UPDATE THE PROPERTY PAGE
   CParamSheet::InitializeDataArray()
```

Script 7: Call graph when loading a scenario using method 2

In fact, Script 7 and Script 6 are identical! The display of the initial distribution is achieved by the function call to `CXDraft::ReadXMLFromDisk_2D`. It is important to understand that this function executes tow actions :

Step 1: It reads from the scenario XML file the position and paramaters of the objects in the terrain (lines, rectangles, ellipses, polylines, polygone and background).

Step 2: It calls for each object fill functions which insert (inside the object or on the borders) agents or obstacles which are generated following the the generation mode stored in the scenario and read in step 1. In other words, the positions of agents and obstacles are NOT stored in the scenario, but generated by MASS from the directives stored for each object (line, rectangle, ellipse, etc..) in the sdcnario.

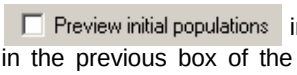
It is important to stress that the method `CXDraft::ReadXMLFromDisk` builds member objects in the instance `CAGNTView::m_draft` of `CXDraft`. **In other words, in this step which consists in opening a scenario, an image of the initial distributions of agents and obstacles is displayed but:**

1) **The cells of the terrain, i.e., the array `CELL* Cell[Xdim*Ydim]` (i.e., the simulation terrain) is neither construction nor initialized**. The terrain is constructed when a simulation is executed, see Script 9 page 37.
2) MASS displays in fact `CAGNTView:: m_draft` in a special window, not in the simulation windows
3) New populations of agents or obstacles are generated each time a scenario is open when a random generation mode is selected. For instance, if you open two times the same scenario which fillup randomly a rectangle with agents of type 0, you will get two different populations of agents.

Loading a scenario means:

- Loading the mission DLLs. They define the policies of the agents.
- Loading the script defining the function plotted by the interpreter. This string is stored in a file with the extension EIC.
- Loading the display parameters of the chart tools.
- Loading the object postions (line, rectangles, etc..) and generating the initial distributions of agents and obstacles.

E.3 Scenario previewing

The previewing of scenarios is an important option of MASS. To preview a scenario, click this the *open file icon* in the left toolbar, which opens the scenario selection box as described above in method 2, then check the "Previous Initial Populations" box (see 

in Fig. 4). This actions will display the initial distributions of the scenario in the previous box of the scenario selection box. The following function calls are executed:

```
int Process_WM_NOTIFY                    (Event function when the check box in checked)
    pnmh->code == CDN_SELCHANGE
            XMLNode::openFileHelper
            AfxRegisterWndClass
            CXDraft::CreateEx
            CView::ReadPlaygroundFromXML
            CView::CXDraft::ReadXMLFromDisk_2D
```

Script 8: Call graph when loading a scenario using method é

The calls from ReadXMLFromDisk_2D are not displayed in Script 7 because they are identical to those shown in the previous scripts.

E.4 Customization

In principle, loading the scenario updates all interface parameters to run immediately a new simulation. However, it is still possible to directly modify the agent parameters accessible in the property pages (described in the paragraph *Interface classes* (see section B page 63), for instance the radius of the sense circle, the cycle time (i.e., the period which separates two actions), etc... It is also possible to select different DLLs (explicitly, there is one DLL per agent population) to change the agent mission or the function displayed in the GRAPH window.

Chapter 2

Agent management in MASS

Population management is based on the synchronous or asynchronous activation of each agent, which then executes its action cycle. We first describe the schelduler, which activates the different agents, then the cycle executed by the activated agent. In the second part, we describe the classes to represent the different objects: cells, agents, terrain, obstacles, etc..

MASS simulates the evolution (moves, generation, disappearance, mutation, etc…) of several populations of agents in a rectangular terrain, possibly also including obstacles. In this section we describe two simulator architectures, namely, the single-thread architecture which was first developed in 2003 and the multi-threaded version 10 years later.

We first describe the model which captures the dynamics of agent populations, then the structure of the simulator based on the single-thread execution, or parallel and concurrent multithread execution.

A Discrete-time Model of population evolvement

Revisions: 1.5 minor, August 2008 JHC

2 major, June 2013, JHC

In this first discussion of the execution models, we only consider for simplicity non-communicating agents. Communicating agents use two schedulers. See section IA page 150.

A.1 General discrete-time model

We follow a discrete-time description of the agent behavior. An agent is an autonomous system which self-activates sequentially at different times. For instance, the agent of index *n* self-activates at

times $T_R(n,m)$ for m=0,1,2….. with $T_R(n,m_1) < T_R(n,m_2)$ *when* $m_1 < m_2$. When it self-activates, we assume that the agent executes the following cycle:

1) It reads a shared memory space denoted $\boldsymbol{R}(n,m)$. In the agent terminology, this space is called the environment of the agent. This space is read at time $T_R(n,m)$. It also reads private data, also defined as its own state variables. We assume that all reading are atomic.
2) It conducts some processing until time $T_W(n,m)$ with the obvious condition $T_W(n,m) > T_R(n,m)$ (see red zones in Fig. 5).
3) At the end of this activity period, i.e., at time $T_W(n,m)$,
   a) it updates data in the subspace $\boldsymbol{W}(n,m)$ of the shared memory space.
   b) It also updates its private memory.
   c) It setups the next read time $T_R(n,m+1)$, i.e., the start of the its next cycle. Note that, because the agent cannot generally predict the evolution of its environment, it cannot really predict its future… and in particular its forthcoming read times!!!
4) Then, we assume that the agent starts a sleep interval (green zone in Fig. 5). During the sleep interval, it does not sense the memory space, i.e., its environment. Thus, the vision is that each agent alternates some periods of activity and inactivity.

The next figure show the execution trace of a three-agent system. It turns out that some agents may be executing in parallel.

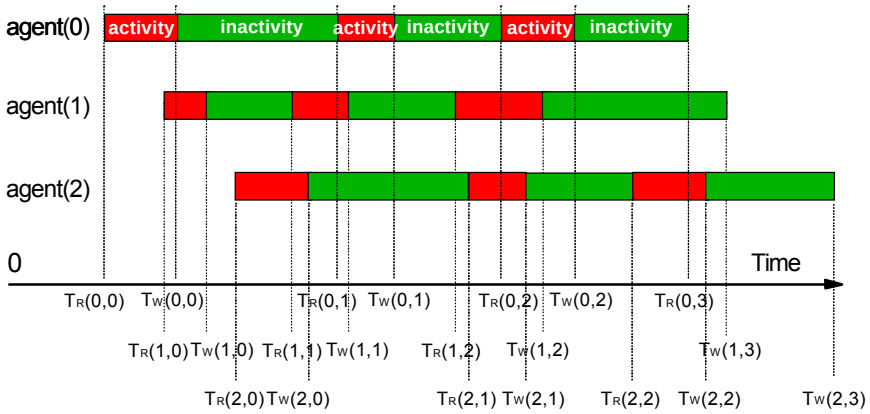


Fig. 5: Trace of Read and Write operations at startup by a 3-agent system

Unfortunately, this execution model generates one problem. An agent reads its memory one sole time at the beginning of the activity phase and writes the memory at the end of its activity period! Thus, writing may be misleading (with respect to its policy) because the environment may have changed between the reading and writing times!!! For instance, consider agent 1 which completes its activity at time $T_W(1,2)$. Now, agent 2 is also active in the interval $[T_R(2,1), T_W(2,1)]$ and $T_W(2,1) < T_W(1,2)$. Thus, the writing planed by agent 1 at time $T_W(1,2)$ may be misleading (with respect to its policy) because agent 2 may have changed the environment before time $T_W(2,1)$. Still more dramatic, agent 1 may disappear in a war game because it is destroyed, annihilated by agent 2 at time $T_W(2,1)$. Thus, one must know what happens in this complex case.

A.2 Atomic model

The agent cycle always follows the cycle described in section A, except that **we assume that the agent is able to read the memory and executes its own processing instantaneously**. Consequently, $T_R(n,m) = T_W(n,m)$. In other words, the activity time is negligibly small compared to the inactivity time. The benefits of this assumption is crucial as the agent writes the memory which is in the state where it read it, and it cannot execute an inconsistent or impossible action. In this approach, the agent sleeps between two read times, and executes an instantaneous action just after a read.

A.3 Real time and simulation time

It is extremely important to stress that the real time and the simulation time are totally different.

- The simulation time is the time needed to conduct the simulation. The faster the simulator activates the agents and caculates their cycles, the shorter the duration of the simulation.
- The real time is the time of the real multiagent system. For instance, let us assume that the simulator starts to calcule the cycle of agent 4 at simulated time $T_R(4,12)$. Whatever the duration needed by the simulator to calculate the cycle (simulation time), the real time is always $T_R(4,12)$ in the real system because of the full atomic model! In other words, at the end of the time interval needed by the simulator to calculate the agent cycle:
    1) The simulated time is always $T_R(4,12)$.
    2) The agent writes its shared and private memory spaces.
    3) The agent knows its NAT that will be $T_R(4,13)$.

  Then, the scheduler identifies the agent with the lowest NAT, say the agent of index *i*. The simulated time hops to $T_R(i,m)$, the NAT of this agent. The scheduler starts the cycle for this agent. Simulated time is then blocked at $T_R(i,m)$. Note that nothing prevents $T_R(4,13)$ to be the lowest NAT. In which case agent 4 will be activated twice consecutively!

This way, the simulator activates all the agents and jumps between the real times $T_R(i,j)$. This process is executed until the top-execution time of the simulation is reached. Aditionnally, the screen shot of the terrain (or the display of any data) is periodically updated to display the progression of the simulation as will be shown below

B Single-thread simulation architecture

Revisions: JHC: Aug 2008, June 2013, Oct 2013. In this first discussion of the execution models, we only consider non-communicating agents. Communicating agents use two schedulers. See section IA page 150.

In this section we consider the full atomic model. We describe the way it is possible to simulate the time evolution of a multi-agent system using a single thread.

B.1 Agents activation by a single thread

In this approach, it is assumed that the scheduler, which activates the agents, knows the next read time of each agent. We also call the next read time " next activation time" (NAT). In principle, each agent is able to determine its NAT at the end of its processing. The single-thread simulator activates the agents in the ascending order of their NATs. Therefore it scans the NATs of all the agents in the existing populations and identify the agent with the lowest NAT. Then, it executes the cycle for this lowest Nat agent in accordance with Fig. 6..

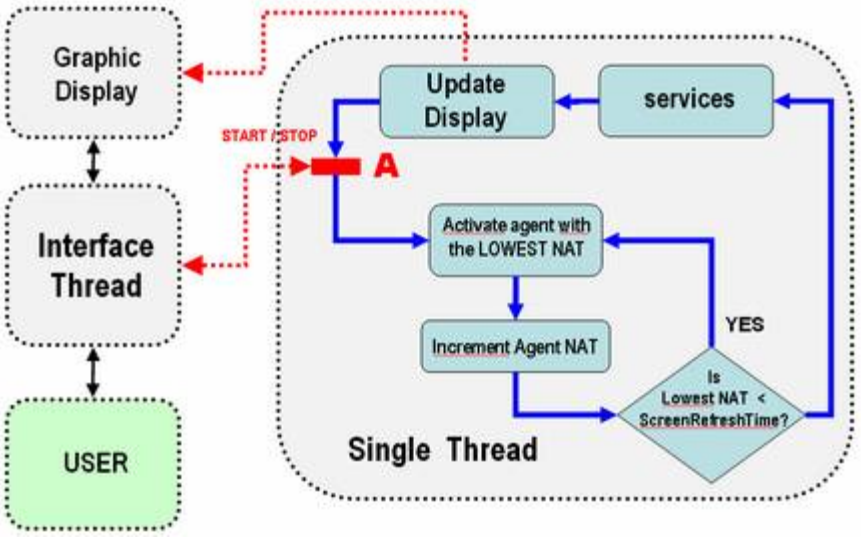


Fig. 6: Single-Thread architecture (simplified version)

The simulation architecture is made up with two threads, namely, the Interface Thread and the processing thread. Concretely:

1) The Interface thread controls a) the Graphic Display (in particular, the display of screen shots with shows the evolution of agent populations), and b) the interaction of the user with MASS.

2) The processing thread activates the agents. The operation is best described considering a simulation session. At startup, the processing thread is blocked at the barrier **A**. The user who clicks the RUN button of MASS opens the barrier and the processing thread follows the processing represented by the blue circuit in Fig. 6. As can be seen, the Single Thread activates sequencially the agents involved in the simulation in the ascending order of their NATs[7]. It identifies the agent with the lowest NAT, and executes the agent processing. Then, the NAT of the processed agent is

[7] *Actually, Fig. 6 is a simplified version of the architecture and several services not integrated in the figure are setup before the loop to activate the agents is executed*

incremented. This loop proceeds until all the lowest NAT of agents exceeds the next screen refresh time. Then, services are executed and the Graphic Display updated.

B.2 Scenario execution: function call graph

Clicking the button `RUN` in the bottom bar (or the button `Rebuild Chart` in any property page) triggers the function `CParamSheet::OnRunSession`. The function calls which follow are listed in Script 9 (latest version Nov 2013).

```
CParamSheet::OnRunSession
    CParamSheet::OnRunSessionSingleThread
          CParamSheet::CheckParams                          //TEST & CHECK CODE
          CParamSheet::SaveAndRebuildAll
               CParamSheet::TransferPage1ParametersToCOREDATA
               CParamSheet::TransferPage2ParametersToCOREDATA
               CParamSheet::TransferPage3ParametersToCOREDATA
               CParamSheet::TransferPage4ParametersToCOREDATA
               CParamSheet::TransferPage5ParametersToCOREDATA
               CParamSheet::TransferPage6ParametersToCOREDATA
               CParamSheet::CheckSizeOfInitialArrays      // TEST & CHECK CODE
               CParamSheet::ReBuildOstaclePopulation
               InitObstacleFromDraft
               CParamSheet::ReBuildAgentPopulation0
                      SCRIPTPROCESSOR::DecodeAgentPolicyString
                      AGENT::Build
                             AGENT.RLEngine::Build
                      AGENT::MapMoveFunctions()          //ALWAYS IN DLL
               CParamSheet::ReBuildAgentPopulation1
               CParamSheet::ReBuildAgentPopulation2
               CParamSheet::ReBuildAgentPopulation3
               CParamSheet::ReBuildAgentPopulation4
               CParamSheet::ReBuildAgentPopulation5
               InitAgentFromDraft_2D  OR  InitAgentFromDraft_3D
               CheckObstaclesInCellArray                  // TEST & CHECK CODE
               CheckAgentPopulations                      // TEST & CHECK CODE

          CAGNTView::StartThread
              ThreadProc                                  //THREAD FUNCTION
                  MainTest
                      MainTestSynchronous                 //IF SYNCHRONOUS MODE
                      MainTestASynchronous                //IF ASYNCHRONOUS MODE
                          BuildActionSet
                          BuildCommSet
                          AddAgent
                          CommunicationMode
                          ActionMode
                              BuildSpatialEnvACTION    //CALL IN THE AGENT DLL
                              FindState                //CALL IN THE AGENT DLL
                              CELLScan                 //CALL IN THE AGENT DLL
```

Script 9: Call graph during the reconfiguration phase in the Single-Thread mode. For simplicity, we did not include the functions called by `CParamSheet::ReBuildAgentPopulation1`, `CParamSheet::ReBuildAgentPopulation2`, `etc..`, which are similar to those called by `CParamSheet:: ReBuildAgentPopulation0`.

There are two steps:

1) Update all parameters in accordance with the selections and customizations executed in the previous phases and start the processing using the agent functions customized in the DLL. These function are grouped together in the upper grayed background.
2) Start the scheduler thread which activates the agents. Calls are displayed in the lower light blue background.

B.2.1.1 Agent allocation in memory

Prior to running any simulation, the **CORE** calls the member functions `CParamSheet::ReBuildAgentPopulationK()` (with `0≤K<AGENTTYPENB`) to delete and reallocate all agent populations in the memory. The numbers `iAMAXNb[i]` and `iAInitNb[i]` (declared in the structure `COREDATA`, see Script 1 page 17) are the number of agents of type `i` allocated in the memory and the number of agents of type `i` defined at the beginning of a simulation, respectively. Allocating more agents than needed unnecessarily wastes the memory with inactive agents and always slows down the efficiency of the agent scheduler in the asynchronous mode (). Two cases are possible:

- When the number of agents iAType=i does not increase during the simulation, the best choice consists in allocating the minimum number of agents, thus `iAMAXNb[i]=iAInitNb[i]`.
- When the number of type-i agents increases during the simulation (for instance because additional agents are generated), it is necessary to allocate from the very beginning more agents than immediately necessary with `iAMAXNb[i]>iAInitNb[i]`.because the **CORE** does not redimension dynamically the agent populations at runtime. Perhaps, this method is not very esthetic, but it privileges the program speed because redimensioning the agent arrays dynamically is time consuming.

An agent can be active, inactive or dead. This property is reflected by the agent member variable `char AgentMode` which can be 'A' (active), 'I' (inactive), 'D' (dead). A dead agent is allocated in the memory but not activated in the simulation session, until it is declared as active. If for instance more Agent0 are allocated that immediately needed (i.e, if `iAMAXNb[0]>iAInitNb[0]`), agents are initialized as follows (see for instance the code in the function `INITGeneA.cpp`):

```
Agent0[i].AgentMode='A' for 0<=i< iAInitNb[0]
Agent0[i].AgentMode='D'  for iAInitNb[0]<=i< iAMAXNb[0]
```

Dead agents are skipped by the scheduler and by the function, which scan the environement.

B.2.1.2 Agent & Obstacle population reconstruction

The **CORE** recreates the agent and obstacle distributions in the terrain from the populations defined in the DRAFT window (see chapter6 page 100). Recall that:

1) When you open a scenario, the CORE generates the agents and obstacles in the object `CAGNTView::m_draft`. It means that each object defined in scenario and stored in `m_draft` (Lines, rectangles, Ellipse, eee) includes a list of points which contain agents of obstacles inside or on the border of the object. This initial generation is achieved automatically when you open a scenario.
2) The methods ReBuildAgentPopulation0, ReBuildAgentPopulation1, etc reallocation the agent population in the memory, **but they do not define the agent positions in the terrain**.
3) The agent position in the terrain are defined in the function InitAgentFromDraft_2D (or InitAgentFromDraft_2D), see green function in the previous script. In other words, This function defines the coordinates of the agents in the terrain from the position of the agents defines for each graphic objecct of the terrain and stored in each object. The precision problem is that agent coordinates in the terrain are `int` when agent postion in object are `double`.

B2.2 Simulation

The simulation thread is directly launched by the function `void CAGNTView::StartThread()`). The thread function is `UINT ThreadProc(LPVOID pParam)` located in the file `ThreadFunctions.cpp`.

In the simulation phase, the **CORE** schedules (synchronously or asynchronously) the agent actions (see the sections 2**Erreur ! Source du renvoi introuvable.** page **Erreur ! Signet non défini.**, and Agent, page 53) At the end of the simulation, it returns to the customization step E.4.

C Multi-thread simulation architecture

Version 1: JHC: Oct 2013. Multi-threading the simulator is extremely important, but unfortunately, the reading of this section is relatively difficult if the you do not already understand the operation of MASS, at least in the single-thread mode. Thus, we suggest at first reading, to skip to section D page 47 to proceed in the understanding of the simulator.

C.1 Activation in parallel of several worker threads

The simulation architecture is made up with an Interface Thread (similarily to the single-thread architecture), a scheduler thread and a variable number of worker threads to activate the agents in parallel (see Fig. 7). Concretely:

1)The Interface thread controls a) the Graphic Display (in particular, the activation of screen shots which shows the evolution of agent populations), and b) the interaction of the user with MASS.

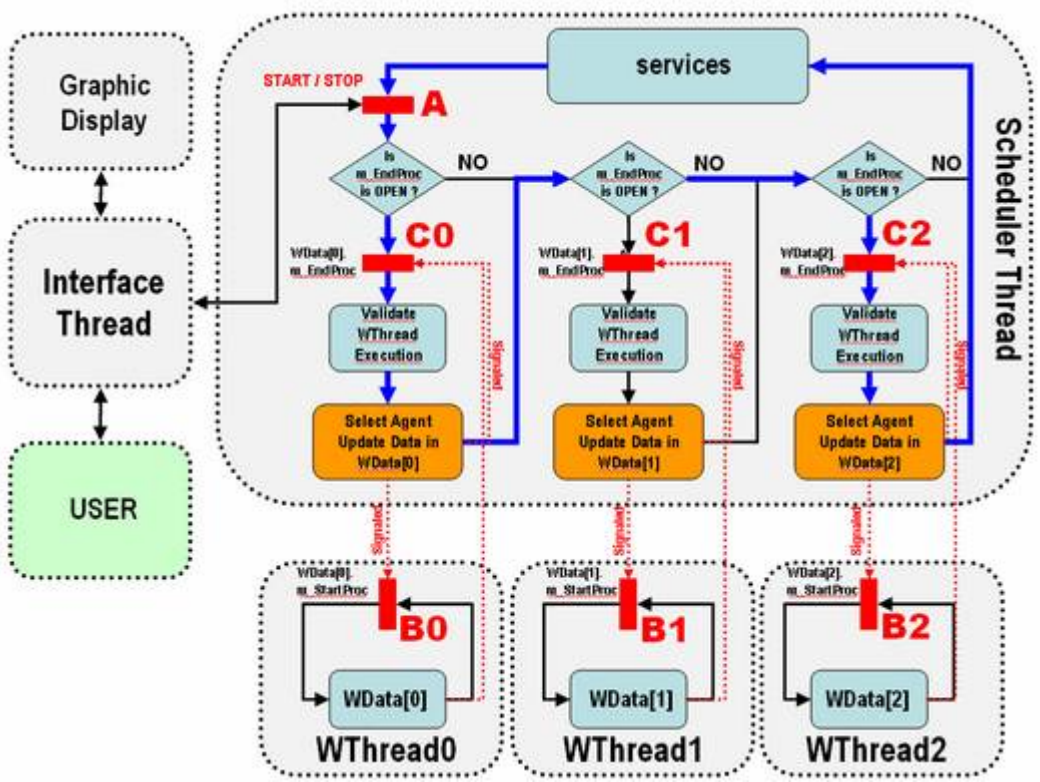


Fig. 7: Multi-thread simulation architecture (simplified version): Example of a Scheduler managing 3 worker threads.

2) The Scheduler Thread controls the activation in parallel of several worker threads. Each worker thread executes the processing of one agent at a time. Fig. 7 shows an example where the scheduler manages three workers threads entitled WThread0, WThread1 and WThread2. The number of worker

threads is defined by the user, but should be reasonably lower than the number of cores in the processor.

The scheduler executes an infinite loop (represented by the **blue** circuit in the figure) which consists in executing various services (triggering screen shots of the agents in the terrain,etc…), and in activating the different worker threads. The crucial point of the figure is the presence of barriers (the red rectangles A, Bi,Ci) which are open or closed to control the execution. To simply understand the operations, let us consider the initial state of the different threads:

Initial State:

- The scheduler is blocked at the START/STOP barrier **A**

- Worker thread 0 (WThread0) is blocked at barrier **B0**. Similarily worker thread 1 is blocked at barrier **B1** and worker thread 2 at barrier **B2**. Thus, all threads (the scheduler and the worker threads) have been created but they are all pending because blocked by barriers.

Start:

The user click 'Start in the interface"! This action opens the START/STOP barrier. The processing executed by the scheduler is shown by the blue circuit.

Activation of an agent in WThread0: The scheduler first tests whether the barrier `WData[0].m_EndProc` is open (i.e., whether the event `WData[0].m_EndProc` is signaled in terms of Win32 programming). Let us assume that it is as in Fig. 7. The barrier is open when the worker thread WThread0 is pending, i.e., blocked at barrier **B0**. Then, the scheduler follows the blue circuit! It passes the barrier and tries to "select the **lowest NAT agent** for WThread0 (see orange block). However, selecting the new agent is a complex question to preserve the order of READ/WRITE operations of shared variables in the memory. We call this question the consistency problem. For the sake of clarity, the discussion is postponed to section C.2. At this stage of the analysis, there are two possible cases:

- If the scheduler discovers a "consistent" agent (say Agent0), it updates the parameters of WThread0 to execute the cycle of Agent0 in the thread, an opens the barrier `WData[0].m_StartProc`. Then, the control of the scheduler follows the blue circuit. Therefore, the scheduler tries to select a consistent agent for WThread1. Opening the barrier `WData[0].m_StartProc` means signaling the event `WData[0].m_StartProc` in MFC programming, and consequently, the worker thread WThread0 passes the barrier **B0** and executes the agent cycle.
- If the scheduler does not discover a "consistent" agent, it simply follows the blue circuit and therefore tries to select a consistent agent for WThread1. Note that it also signals the event `WData[0].m_EndProc` to reopen the barrier **C0** as it switched to the "close state" when the scheduler passed it.

Activation of an agent in WThread1: The activation of an agent for WThread1 is totally similar to the processing described just above for WThread0. As shown by the blue circuit in Fig. 7, the scheduler tests whether the barrier **C1** is open (i.e., whether the event `WData[1].m_EndProc` is signaled). Let us assume that it is NOT as in Fig. 7. Then, the scheduler follows the blue circuit and proceeds with the discovering of a consistent agent for WThread2.

Activation of an agent in WThread2: Again, the activation of an agent by WThread2 is totally similar to the processing described just above for WThread0. The barrier **C2** is open in Fig. 7. Thus, the scheduler will try to find a consistent agent and to activate the worker thread WThread2 to process this agent..

Execution of services: The blue circuit shows that the scheduler executes services and start a new cycle to activate new agents if worker threads are pending. It is crucial to underline the following points:

The scheduler will try again to discover a consistent agent for WThread0. We must stress the following points:

- If the scheduler failed to discover a consistent agent at the preceding cycle for WThread0 (for example), the barrier `WData[0].m_EndProc` is **OPEN**! It is because the scheduler signaled the event `WData[0].m_EndProc` at the en of the previous cycle.
- If the scheduler succeded to discover a consistent agent at the preceding cycle for WThread0, the barrier `WData[0].m_EndProc` remains CLOSED so long as the processing of WThread0 is not complete! It is because the Worker0 signals `WData[0].m_EndProc` only at the end of its own processing (see Fig. 7). Thus, the WThread0 CANNOT be reactivated so long as its own processing is not terminated.
- The scheduler WThread0 Is blocked at the barrier `WData[0].m_StartProc` at the end of its processing. It is because this barrier becomes blocking when it passed it at its previous cycle. Thus, the worker threads does not terminate! It becomes pending at the end of its processing at the barrier **B0** (see Fig. 7). In other words (to be totally clear): When the WThread0 terminates its agent processing, its signals the event `WData[0].m_EndProc` which opens the barrier **C0**. Thus, the scheduler can try to select a consistent agent for WThread0 and reopen the barrier **B0** for another processing.

C.2 Reuse of Single-Thread DLLs in Multi-Thread execution

The ascending compatibility of DLLs, i.e., the reuse in the multi-thread architecture of the DLLs written before the consideration of parallelism in MASS, is an important question. Let us review the possible executions

C2.1 Single-Thread execution (action mode)

The control of the execution is in the CORE. The figure below details the blue processing loop of Fig. 6. The names of the different functions involved in the processing have been added in the green color. It is the function `MainTestAsynchronous` which activates sequentially the agents in the ascending order of their NATs. It calls `ActionMode` which calls the relevant functions **in** the DLL of each agent. When the agent is terminated in the DLL, there are three necessary updates:

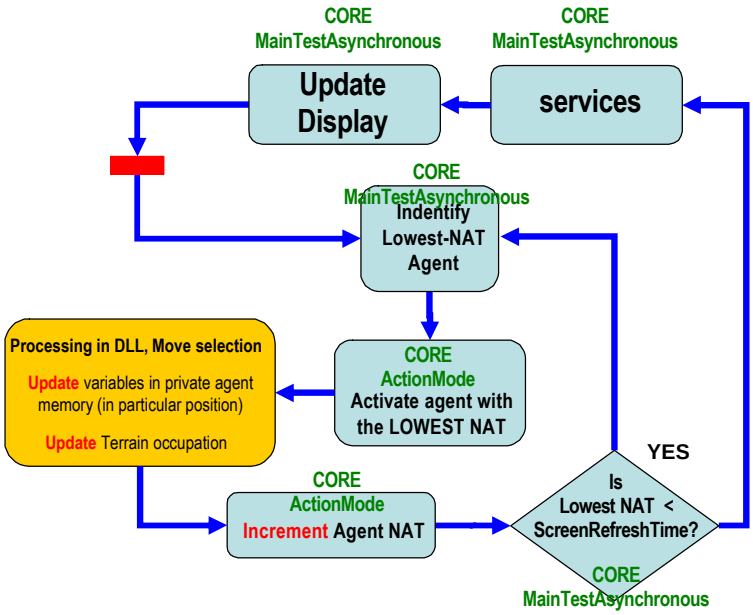


Fig. 8: Function calls in the ST execution. Green text shows the function names in the CORE and the orange form (compare with Fig. 6) shows the external function called in the agent DLL. Red text shows where code to update data, partly in the CORE, partly in the DLL.

Update the internal variables of the agent. This operation is conducted in the agent DLL. In the "old-style" DLLs, the update code may be disseminated across the DLL! When the "incremental execution mode" is selected, the update may be in the block `CellProcAction.cpp` (or `CellProcAction.h`) and when the "incremental execution mode" is not selected, the update is in the function `ScanFineDecisionTree`. In some DLLs, the update code may be in the function CheckFinalCellAndUpdate_2D**.** This relative "anarchy" comes from the fact that the DLLs were written by different authors who chose different code of coding.

1) Update the terrain, to account for the possible new positions or the disappearance of agents. This code is in the function **`ActionMode`** of the CORE, after the execution of functions in the DLL.

```
/UPDATE CELL STATE: REMEMBER THAT IN THE ASCII TABLE, CHAR(49)='1'
Data->Cell[pAgent->Z*XDim*YDim+pAgent->X*YDim+pAgent->Y].State[0]=CHAR(49+iType);
Data->Cell[pAgent->Z*XDim*YDim+pAgent->X*YDim+pAgent->Y].iRank=iRank;
```

2) Update of the next action time of the agent, also performed in the function `ActionMode`

```
/ UPDATE NEXT ACTION TIME (NAT)
Agent->ActionTime[0] = pAgent->ActionTime[0] + pAgent->DActionTime;
```

As this implementation works for ten years, it must be preserved to the maximum even if we search for the ascending compatibility of DLLs in MT execution. Modifying the above CORE functions is possible but difficult if the changes force to modify all existing DLLs. The best solution would be to structure de MT code so that MT execution would be possible with the existing DLLs. Let us analyze now how the simulator operates in case of Multi-Thread execution. We distinguish two Multi-Threading modes.

C2.2 Multi-Thread execution with precontrol of consistency

C.2.2.1 Activation of agents:

1) As shown in Fig. 7, the activation of agents is controlled by the scheduler which is integrated in the CORE. Fig. 7 shows that the function `SchedulerProc` allocates the agents to the

different worker threads. The allocation is sequential **BUT** the executions of the worker threads overlap and thus reduce the simulation time. There are two problems which do not exist in the Single-Tread execution.

Preservation of the activation of agents in the ascending time of NATs

We distinguish two cases:

A) In the simple cases, the scheduler knows the NAT of the agents in progress (in the worker threads). This occurs for instance when the time increment between two NATs is constant. In this case, the scheduler can find the next agent with the lowest NAT. It may be a pending agent (i.e., an agent not activated) or an agent in progress in a worker thread. Of course, if the lowest-NAT agent is in progress, it will not be activated until the completion of its current cycle. If the lowest-NAT agent is NOT in progress, the scheduler will check whether it is consistent as will be discussed below.

B) In the most-general case, the scheduler does not know the NAT of an agent in progress (in a worker thread) until the end of the worker thread processing, because the NAT depends on the environment evolution which is totally unpredictable! The agent has a vision of the world after the scan of its environment. Thus, how finding the next lowest-NAT agent if we do not know when will be reactivated the agent in progress ? It is impossible to warrant that the increasing oder of NATs will not be violated !!!!! Strictky, it seems that there is no general solution without addtionnal assumptions.

Preservation of the consistency

The so-called “strict consistency” for a multi-threaded execution consists of preserving the strict order of the READ and WRITE operations (occurring in a single-thread execution) for the variables shared by different threads. Activating the agents in the ascending order of their NATs duplicates the execution in the real space and preserves the order of READ operation only! It is strictly impossible to preserve the ordering of READ and WRITE if the NATs of the agent in progress are unknown.

To circumvate this issue, we shall follow a weak-consistency approach. It is weak because the strict temporal ordering may be violated, but this should not dramatically affect the processing[8].

> As the NATs of the agents under processing are unknown, the scheduler retreives the lowest NAT exclusively in the set of pending agents. I**f the lowest-NAT agent shares no memory with those in progress, it is activated**.

This approach is *palliative* because it is not garanteed that one or several agents in progress will not be terminate quicky in the real word (independently of the thread execution time) and should be reactivated quickly in the future before the lowest-NAT agent that was discovered and activated. Let us consider the following example for the sake of clarity: Agent1 (in progress) is a predator hunting a prey. Agent2 is the prey. It is pending, The scheduler discovers that Agent2 is the the lowest-NAT agent to be activated at time T2. Then, **it activates it because Agent1 is outside the sens disk of Agent2**. However, the NAT of Agent1 in progress (say T1) may be lower than T2, so that the correct ordering of write-read operations may be incorrect. This case occurs for instance if Agent1 wrote inside the sense disk of Agent2 at T1, because starting immediately Agent2 at T2 makes that Agent2 reads it sense disk that will be incorrect. However, **it is implicitely admitted that when two agents are distant and beyond their sense disks, they cannot significantly impact their states.** Thus, it is hoped that the violation of the correct order of activation will not impact the dynamics of agent population. Again, The final validation should consists in checking whether Multi-Thread executions is faster than Single-Thread execution, but identical.

[8] *Ultimately, the validation of this approach consists in checking whether the Multi-Thread execution is faster than the Single-Thread one, but provides identical data for the case under consideration.*

C2.3 algorithm to find consistent agents

The algorithm described in section **Erreur ! Source du renvoi introuvable.** may be viewed as the base algorithm that may be summarizes as follow: *The scheduler never starts a new lowest-NAT agent so long as one of the agents in progress in the worker thread(s) shared data with it*. Concretely, the lowest-NAT agent (say Agent1) is not activated if it shares data with Agent0 in progress. But why not considering to activate the second lowest-NAT agent (say agent2) if it is consistent with Agent0 AND Agent1, or in other words if Agent2 shares no data with Agent0 nor Agent1? In this approach, the activation of some consistent agents is out of order.

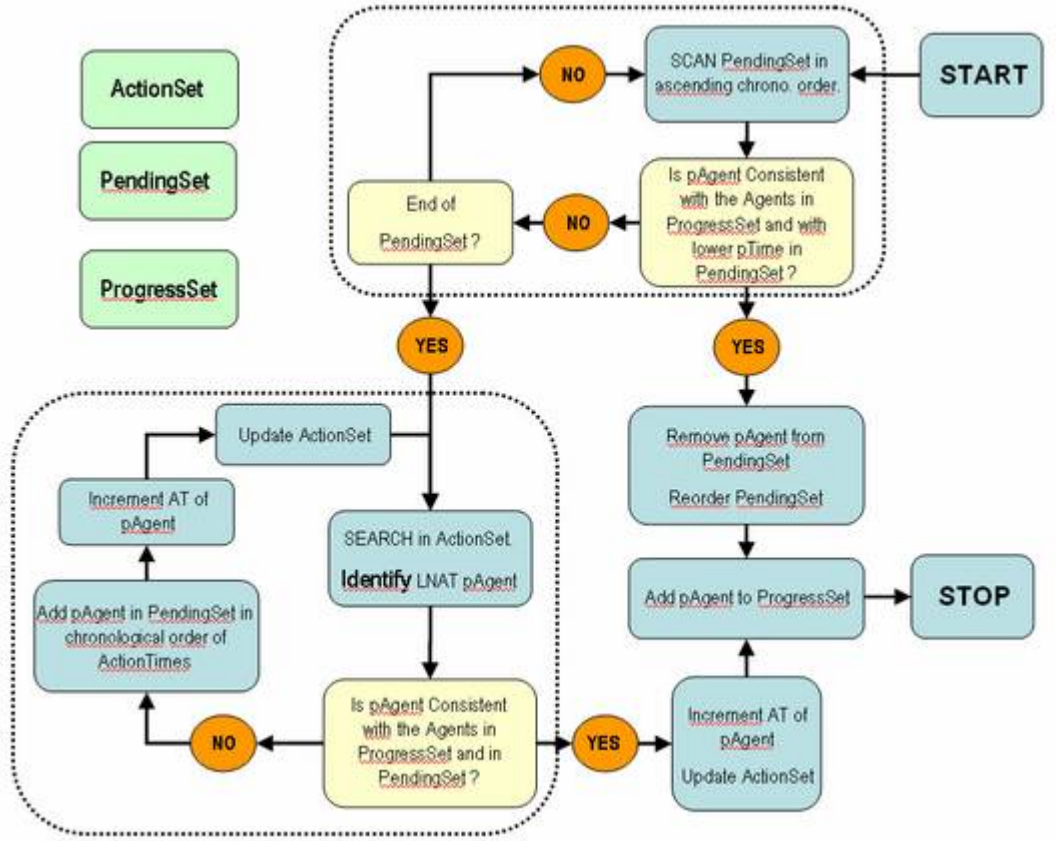


Fig. 9: Accelerated algorithm to discover consistent agents

C2.4 Default consistency models

Ultimately, the validation of the consistency model is difficult. The empirical approach consists in comparing several mulithreaded executions (based on different consistency models) and the single-threaded execution, so as to observe whether the multiagent system evolves in all cases in the same way. The benefits expected from multithreading is a reduction of the simulation times.

It is the user responsibility to implement case-dependent consistency models in the agent DLL. However, two defaut consistency models are integrated in the CORE, namely:

1) No consistency constraint. The scheduler activated the lowest-NAT agent without restriction.
2) An agent is activated if no agent in the Progress Set (i.e., under execution in the worker threads) or in the Pending Set is in its sense disk. This conditions is relatively logical as the agent does not see these agents, and there may start a cycle.

C.3 Implementation

C3.1 Default consistency models

Fig. 10 below details the execution control displayed in Fig. 7. The names of the different functions involved in the processing have been added in the green color.

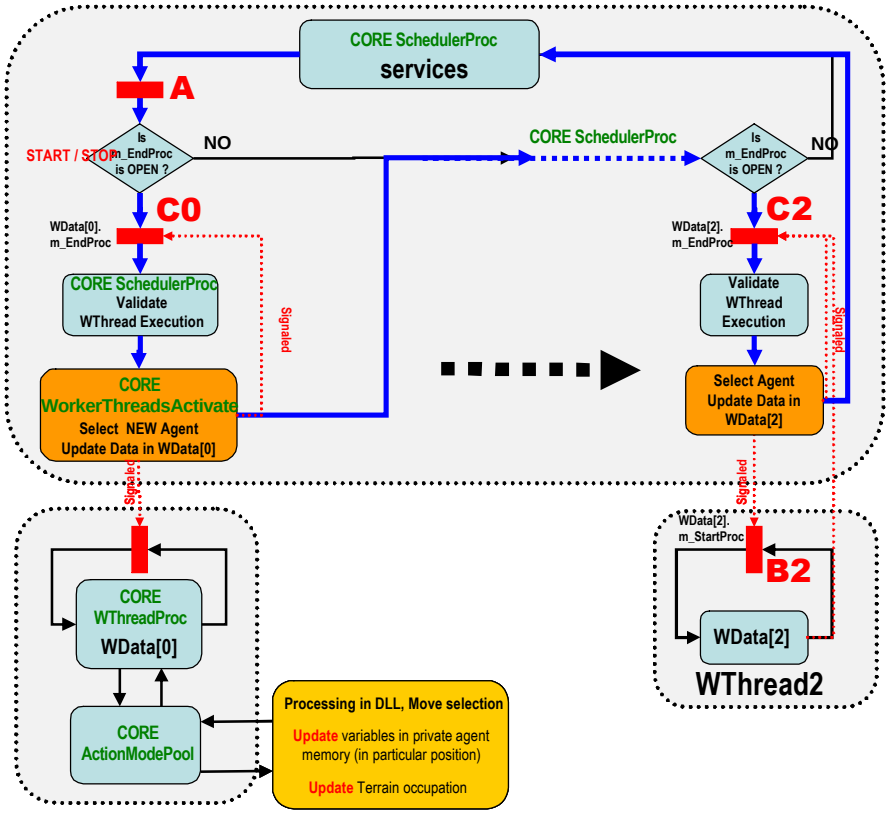


Fig. 10: Function calls in the MT execution. Green text shows the function names in the CORE and the added yellow form (compare with **Fig. 7**). The figure highlights the calls and updates in MT.

The simulator conducts the following actions to identify the next agent (say AgentA) to be activated:

1) The sheduler function `SchedulerProc` calls `WorkerThreadActivate` (see the ORANGE form), which calls `SelectAndStartNewAgent.`
2) This function retrieves the lowest-NAT agent (say Agent1), and checks that no agent in progress is inside its sense disk. This is the consistency control. Recall that The idea behing this approach is that the order of READ-WRITE may be violated, but this will occur when the agents involved in the time violation are so distant that it should not really modify the population dynamics. It is not violated when agents are closed.
3) If it is, `SelectAndStartNewAgent` updates the data `WData[0]` of thread `Wthread[0]` and opens the barrier which blocked it (see the code in `SelectAndStartNewAgent`).
   The execution in the worker thread is in the function `WThreadProc`. This function calls the function `ActionModePool` if the agent cycle is an ACTION cycle and the function `ComModePool` it the agent cycle is a communication cycle (actually, the code for communication cycle is not written 131001). **We stress that all the calls to functions in the agent**

DLL are located in `ActionModeCycle`. The calls to the agent DLL are similar to those conducted in `ActionMode` in the Single Thead execution.

4) So far, we have not explained how the CORE (i.e, the function `SelectAndStartNewAgent`) updates the NAT of the selected agent that is to be executed in `Wthread[0]`. This is a real problem because the function `SchedulerProc` will pass to the next worker thread `Wthread[1]` and if it is pending, it will try to find the next lowest-NAT agent for this thread. The NAT of Agent1 allocated in `Wthread[0]` must be incremented to make that another agent may be selected for `Wthread[1]`…. and so on. Actually, the trick consists of setting **provisorily** the NAT of Agent1 to a very large number (for instance FLOAT_MAX of the machine). Thus:
   - The search for the lowest-NAT agent can be conducted in the set of all agents as the agents in progress cannot be reactivated.
   - The NAT of Agent1 will updated at the end of its processing by the Wthread[0] to its exact value that will be known at this time.
   - Where in the code could we update the agent NAT? In the most general case, the next NAT of the agent (i.e., `AGENT::ActionTime[0]`) is calculated in the DLL! However, as shown in the ST mode described it, is updated in the function `ActionMode`.
   - Thus, for reusing the DLLs in the MT mode, one may consider to update the Cell and the agent NAT in the function `ActionModePool`, **AFTER THE CALL TO THE AGENT DLL**, the code already shown in section C2.1, namely:

```
//UPDATE CELL STATE: REMEMBER THAT IN THE ASCII TABLE, CHAR(49)='1'
  Data->Cell[pAgent->Z*XDim*YDim+pAgent->X*YDim+pAgent->Y].State[0]=CHAR(49+iType);
  Data->Cell[pAgent->Z*XDim*YDim+pAgent->X*YDim+pAgent->Y].iRank=iRank;
//UPDATE NEXT ACTION TIME (NAT)
  Agent->ActionTime[0] = pAgent->ActionTime[0] + pAgent->DActionTime;
```

C3.2 Graph of function calls

Clicking the button `RUN` in the bottom bar (or the button `Rebuild Chart` in any property page) triggers the function `CParamSheet::OnRunSession`. The function calls which follow are listed in Script 9 (latest version Nov 2013).

C.4 Scheduler & worker threads implementation

Let us reuse the example introduced in the previous paragraph and assume that a worker thread (say thread 1) starts to calcule the cycle of agent 4 at simulated time $T_R(4,12)$. If the simulator waits for the completion to start another worker thread, there is no parallelism of execution and no speedup of the simulator. The fundamental question concerns the knowledge of the NAT of agent 4. There are two cases:

How does the agent react if the action it planed cannot be executed? How does the environment react to this impossible action? Several execution models are possible:

Model 1:• Atomic model: The activated agent constructs instantaneously its environment states and executes instantaneously its action. We use this atomic execution model.

Model 2:• Non-atomic models: In these models, the construction of the environment and the calculation of the action Each time the agent samples its environment, it compares it to its previous representation. If it has changed, the agent checks whether the action it planed to execute is still possible.

- If it is, it assumes it was executed and samples the environment including the consequence of its action. If it was not, it assumes that the action was not carried out.

D Agent implementation

In this introduction to scheduling, we only consider for simplicity non-communicating agents. Communicating agents use two schedulers. See section IA npage 150.

In practice, each agent has 2 member variables to control the successive cycles:

- `float ActionTime[ITERATNB]`: The agent stores in this array its last action times, where `ITERATNB` is defined in `Global.h`.
  - `ActionTime[0]` is the agent next-action time (NAT). When the agent is not active, it is the time when the agent is to be activated to execute its next cycle.
  - The other times `{ActionTime[i]|1<i<ITERATNB}` are past action times with `ActionTime[i]<ActionTime[i+1]`.
- `float DActionTime` is the time interval separating two action times. Note that the time increment `DActionTime` is not necessarily constant. Each agent may dynamically change it depending on its own state automaton.

Each agent is activated by a global scheduler when time equals its NAT. Thus, the scheduler manages the temporal order of agent activations. It is encapsulated in the class `SCHEDULER` described below in paragraph **Erreur ! Source du renvoi introuvable.**. The scheduler operates as follows:

1. It stores in a single array <u>all</u> agent NATs, i.e., the elements `{Agent[i][j].ActionTime[0]|0≤i<AGENTTYPENB,0≤j<iAMAXNb[AGENTTYPENB]}`.
2. It identifies the lowest NAT.
3. Then, it triggers the ACTION cycle of the corresponding agent.
4. At the end of its cycle, the agent shifts its action times (i.e., `ActionTime[i+1]=ActionTime[i])` and and increments `ActionTime[0]` (i.e., `ActionTime[0]= ActionTime[0]+ DActionTime`).
5. Then, the agent returns the control to the scheduler, which retrieves the next lowest NAT (step 2), triggers the cycle of the corresponding agent, and so on. Note in passing that the scheduler can trigger several times consecutively the same agent if the agent has a very small `DActionTime` and thus increments very litte its action time in step 4.

D.1 Fast algorithm to retrieve the lowest NAT

(**Revision: June 2013, JHC**)

D1.1 Principle

Writing a fast algorithm to retrieve the lowest NAT is not so easy. The simplest solution consists in scanning all agents to identify the one with the shortest NAT. However, this brute algorithm scales linearly as the total number N of agents, and dramatically slows down the execution speed when there are typically thousands of agents. It is necessary to consider some more sophisticated approach to identify more rapidly the lowest Next Action Time (denoted LowestNAT) from the NAT array. We build the following NATInfo structure:

```
typedef struct {
```

```
////////////////////////////////////////////////////////////////////////////////
// THIS STRUCTURE GROUPS TOGETHER POINTERS TO THE NAT (NEXT ACTION TIME) OF
// EACH AGENT
////////////////////////////////////////////////////////////////////////////////
       float ** pNAT; // ARRAY OF POINTERS TO Next Node Time OF EACH AGENTS
       AGENT** pAgent;
       int iAgentNb;
}NATInfo;
```

Code 1: NATInfo structure declaration

Let `pNatInfo` be an instance of this structure. Then, `pNatInfo.pNAT[i]` points to the NAT of the agent `pNATInfo.Agent[i]`. Of course, scanning this one dimension array `pNatInfo.pNAT` enables retrieving the lowest NAT and to identify the corresponding agent.

Now, to illustrate how to speed up the identification of the agent with the lowest NAT, let us consider the example displayed in the next figure. There are 27 agents. The array `pNatInfo.pNAT[i]`is split is 3 subarrays (level 1), namely the array [1,9], [10,18], and [19,27]. Let us assume that we know the index I_1 of the agent with the lowest NAT in the array [1,9], the index I2 of the agent with the lowest NAT in the array [10,18], and similarily the index I3 of the agent with the lowest NAT in the array [19,27]. Then this splitting procedure is iterated to level 2. For instance, the array [1,9] is split in three subarrays [1,3], [4,6] and [7,9] and we assume that we know the index of the agents with the lowest NAT respectively in [1,3], [4,6] and [7,9]. This processing is also applied to the level 1 arrays [10,18], and [19,27].

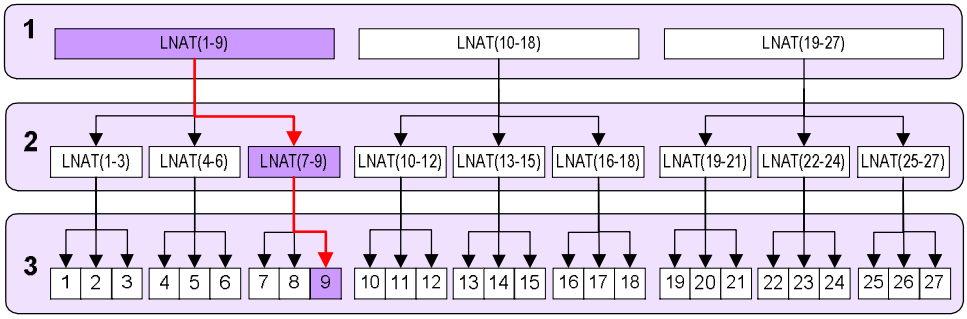


Fig. 11: Tree of LNATs and NATs for 3-layer decomposition of `pNatInfo.pNAT`

Now, let us assume that in a first step, we have develop an algorithm which determines for each interval (i.e., in level 1 and 2):

1) The index of the first agent of the interval,
2) The index (denoted iLowestNAT) of the agent with the lowest NAT in each interval.

For clarity, let us consider Fig. 11 and that the agent with the lowest NAT is that of index iLowestNAT=9 in [7,9]. The figure shows that iLowestNAT(1,9) =LNAT(7,9) =9 (see the purple blocks in the figure) ! The sole comparision of the LNATs of [1,9], [10,18], and [19,27] in level 1 is needed to retreive the index of the lowest-NAT agent! This number must be compared to the 27 comparisons needed in the brute scan of the array `pNatInfo.pNAT`.

Now, let us consider that the agent of index 9 is activated and increases its NAT. Consequently, the algorithm must update the LNATs of all the purple sets in Fig. 11. This forces 3 comparisons in level 3 to update the LNAT for the set [7-9] in level 2. Then, 3 comparisons of the LNATs are needed in layer 2 to update LNAT for the set [1-9]. Thus, 6 comparisons are needed to update the different levels of Fig. 11. At all, 9 comparisons are needed to update the LNATs and to extract the LNAT of the whole set of times. This algorithm is 3 times faster than the brute initial algorithm.

Consider the general case with N1 leaves (i.e., agents) of the lowest layer are grouped py k to a node in the upper layer. Thus, this node will control N1xk leaves. If the nodes of this layer are also grouped

by k, a node in the upper layer will control N1xkxk leaves and so on. Thus a tree wih N layers will described N1xk^N leaves, i.e., agents. Thus, $N_A = N_I k^{N_L - 1}$, where NL is the number of layer.

Example: $N_L = 1$. Thus, one sole layer. Then; $N_A = N_I$, that is regular because there is one sole layer.

Example: $N_L = 3$, just a in Fig. 11. If $N_I = 3$, then $N_A = 3k^2$. In Fig. 11, $N_A = 27$, thus, the solution is trivial.. $k = 3$.

when a node in the tree connects k nodes of the lower level, the total number of agents . Then $N_A = k^{N_L}$.

If the tree has one sole layer, the top interval is not split and includes N_A agents

If the tree has two layers, the top layer is split in k elements, and each elements is connected to k elements of the lower layer.

(9).

D1.2 Implementation

The fast identification of the agent with the lowest NAT following this algorithm is achived by the class `CTimeIntervals` written by Fabien Bayol in February 2003 The number k of recursions is an adjustable parameter. In practice, it turns out that (contrarily to the "theoretical" behavior expected from the analysis in the previous paragraph), the fastest identification of the agent with the lowestNAT is achieved when k is not larger than 2 or 3. The code is typically as follows:

To setup the NATInfo structure and build a CIntervals instance

```
//SECTION TO INITIALIZE A NATInfo STRUCTURE TO BUILD A CTimeIntervals INSTANCE WHICH
//SPEEDS UP THE EXTRACTION OF THE SHORTEST ACTION TIME OF ALL AGENTS
    NATInfo* pNATInfo = BuildNATInfo(pData->iAMAXNb, pData->Agent);
    CTimeIntervals ActionTimes;//CREATE TIME INVERVALS TO QUICKLY RETREIVE THE SHORTEST NAT
    if (pNATInfo->iAgentNb > 15) ActionTimes.Build(pNATInfo->pNAT,pNATInfo->iAgentNb,3);
    else ActionTimes.Build(pNATInfo->pNAT,pNATInfo->iAgentNb,1);
```

To retrieve the lowest NAT, simply call:

```
   iLowestNAT = ActionTimes.getLowestNTRank();//GET INDEX OF LOWER NAT IN ActionTimes
   float lowestNAT = *pNATInfo->pNAT[iLowestNAT];
```

To update the array of LNATs, simply call:

```
        ActionTimes.Update(pNATInfo->pNAT);
```

Code 2: Code to quickly identify the agent with the lowest NAT

WARNING: At the moment, the generation of new agents activates inactive agents at the end of the screen refresh period as a residue of the Old synchronous mode described below. The NATs of

(9) Consider only two levels in Fig. 5, and N agents splits in n1 intervals

- In level 1 consists in comparing the LNAT(i) of the n_1 intervals to identify the interval which includes the lowest NAT. This operation costs n_1 comparisons.
- In level 2, there are N/n_1 comparisons. The total algorithm costs n_1+N/n_1 comparisons. This count is minimum when $n_1 = \sqrt{N}$, and costs in that case $2\sqrt{N}$ comparisons instead of N comparisons for the brute method.

inactive agents evolve similarly as those of active agents. This way of adding agents will have to be clarified.

D.2 Integration of the scheduler in *MainTestAsynchronous*

Fig. 12 depicts the integration of the scheduler in the function `void MainTestAsynchronous(COREDATA* pData)`. For simplicity, we consider here non-communicating agents, although the code is slightly more complicated when all agents can potentially communicate, and therefore use a double scheduler to manage two possible operation cycles. The operation described in Fig. 12 is more complicated than that represented initially in **Erreur ! Source du renvoi introuvable.**, because the program here:
Considers that some agents are not active.
Calculates displayed data and refreshes periodically the display.
Refreshes the scheduler tree as explained previously.
Enables the thread abortion.
Generates new agents.

We detail the different steps:

- **Step 1**: Test whether the maximum simulation time (MSTime) is greater than next Screen Refresh Time (SRT). If MSTime>SRT, exit Scheduling of agents and return the control to the interface for another simulation. If MSTime<SRT, go to step 2.
- **Step 2**: Retreive the LNAT from the NAT array, and identify the associated Agent.
- **Step 3**: Test whether the LNAT is smaller than the screen refresh time (SRT)? If it is, test whether the agent is active or not (see the blocks 4 in Fig. 12).
- **Step 4**: If agent is active, transfer the control to the agent, which excutes its ACTION cycle (following agent's policy).

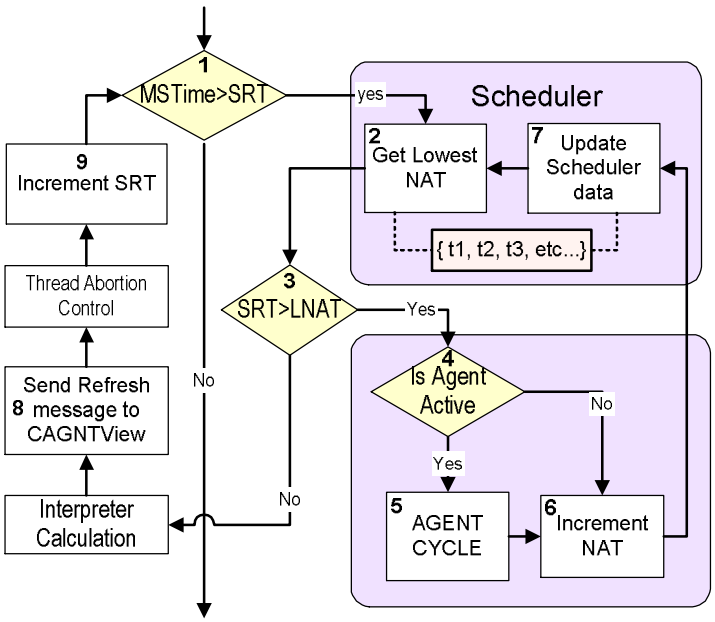


Fig. 12: MainTest and Scheduler interactions flowchart.

- **Step 6**: Update agent's NAT. Each active agent directly executes this operation at the end of its ACTION cycle. If the agent is inactive, the NAT is artificially increased to a high value (when the agent became active, the NAT is initialized to a coherent value).
- **Step 7**: The scheduler's data be recalculated according to the NAT array, to consider the agent's NAT evolution.
- **Step 8**: If SRT>LNAT, the screen is refreshed (charts or 2D display).
- **Step 9**: Increment the SRT for the next screen refresh.

Now, we can understand the code in the fuction `MainTestAsynchronous`, in particular the integration of the scheduler. In fact there are two schedulers in the general cases when agents can communicate. One is the `ActionScheduler`, which exits for all agents, and the second one is the `pNodeSchedulerArrays`, which is activated for communicating agents only. In this context, an agent has an `ActionTime` array (as explained previously) and a `NodeTime` array, for communications.
Line 01, the `ActionScheduler` retrieves the index `iNAT` of the agent with the LNAT.
Line 02 retrives the lowest NAT!
Line 05-06 retrieves the lowest NNT for communicating agents
Line 09 compares the two lowestNAT and lowestNNT to the `ScreenRefreshTime`. If one is smaller than the SRT, an agent cycle is actived, either a communication cycle with the function `NodeMode` (see line 12) or an action cycle with the function `ActionMode` (see line 21)

```
void MainTestAsynchronous(COREDATA* pData)
////////////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////////////
{
  ....................................
  ....................................
  ////////////////////////////////////////////////////////////////////////////
  while(ScreenRefreshTime<=MaxTIME) {                  // MAIN LOOP
        ////////////////////////////////////////////////////////////////////////////
          // SECTION TO //FORCE STEP BY STEP EXECUTION
          ....................
        ////////////////////////////////////////////////////////////////////////////
          //SECTION TO CONTROL THREAD ABORTION
          ....................
        ////////////////////////////////////////////////////////////////////////////
          //SECTION TO GENERATE AGENTS AT RUNTIME
          ....................
        ////////////////////////////////////////////////////////////////////////////
          //SECTION TO SCAN AGENTS UNTIL NEXT ACTION AND NEXT NODE TIMES ARE LARGER
          //THAN NEXT SCREEN UPDATE!!!!
01              iNAT = ActionScheduler.getLowestNATRank();
02              float lowestNAT = *pActionSchedulerArrays->pNAT[iNAT];
03              float lowestNNT;
04              if (pNodeSchedulerArrays->iNodeNb != 0) { //THE NETWORK SCHEDULER WAS CREATED
05                      iNNT = NodeScheduler.getLowestNATRank();
06                      lowestNNT = *pNodeSchedulerArrays->pNNT[iNNT];
07              }
08              else lowestNNT = (float) pow((float)2,31)-1;
09              while(ScreenRefreshTime>lowestNAT || ScreenRefreshTime>lowestNNT) {
10                      if (lowestNNT<lowestNAT) {  // AGENT COMMUNICATES
11                              AGENT* pAgent = pNodeSchedulerArrays->pAgent[iNNT];
12                              NodeMode(pData,pAgent,LookUpTable);    //<--- IMPORTANT
13                              pAgent->iNODECycleNb+=1;
14                              pAgent->iNODEFastFullNb+=1; //RANDOM INITIALIZATION
15                              // SCHEDULER UPDATE WITH NEW NNT
16                              NodeScheduler.Update(pNodeSchedulerArrays->pNNT);
17                              iNNT = NodeScheduler.getLowestNATRank();
```

```
18                              lowestNNT = *pNodeSchedulerArrays->pNNT[iNNT];
19                          }else {                     // AGENT ACTS
20                              AGENT* pAgent = pActionSchedulerArrays->pAgent[iNAT];
21                              ActionMode(pData,pAgent,LookUpTable);  //<--- IMPORTANT
22                              pAgent->iACTIONCycleNb+=1;
23                              pAgent->iACTIONFastFullNb+=1; //RANDOM INITIALIZATION
24                              // SCHEDULER UPDATE WITH NEW NAT
25                              ActionScheduler.Update(pActionSchedulerArrays->pNAT);
26                              iNAT = ActionScheduler.getLowestNATRank();
27                              lowestNAT = *pActionSchedulerArrays->pNAT[iNAT];
28                          }
29                  }
  ////////////////////////////////////////////////////////////////////////////
          ......................
          ......................
          ......................
  }
  ////////////////////////////////////////////////////////////////////////////
  ......................................
  ......................................
}
```

Script 10: Scheduler implementation and agent activation in `MainTestAsynchronous`

E Synchronous scheduling

Nota: **This section persists in the CORE manual for "historical" reasons because MASS initially operated in the pure synchronous mode. However, we recommand using the asynchronous mode exclusively, as it operates in the synchronous mode when all `DActionTime` are equal**.

The selection between synchronous or asynchronous activation of agents is automatically defined in the Check Box entitled "Synchronous mode" is selected in ParamPage2 (see Fig. 17 page 64). The synchronous mode is executed in the function `void MainTestSynchronous(COREDATA* pData)` and the asynchronous mode in the function `void MainTestAsynchronous(COREDATA* pData)`.

The flowchart of the synchronous mode is represented in Fig. 13 below, which shows that each time iteration consists in executing 2 imbricate loops, one for the populations, and one for the agents.

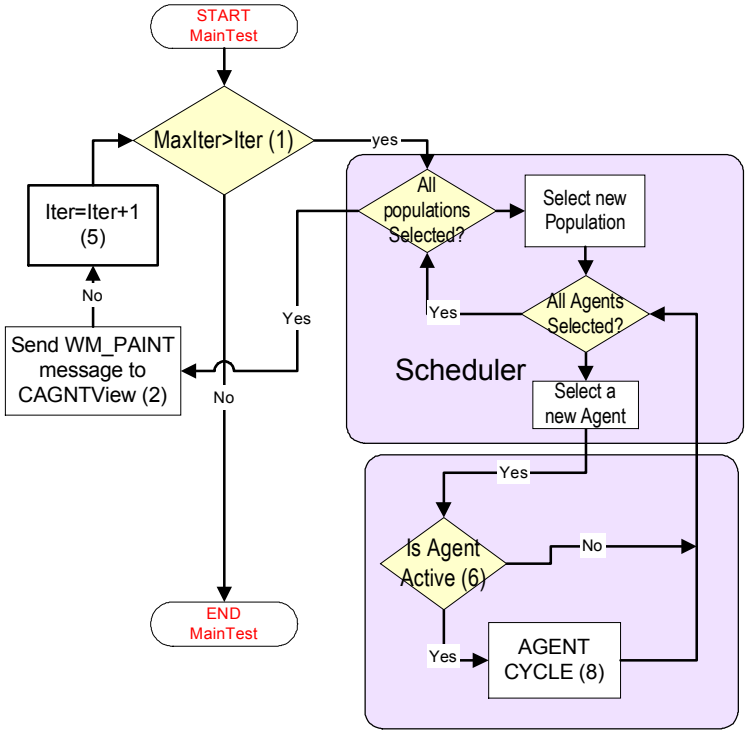


Fig. 13: MainTest and Scheduler interactions flowchart (**synchronous** mode)

In the revision in Oct 2002, all agents sample their environment (i.e., construct their environment table) at the same frequency and move on the grid at the same top speed, namely one cell per cycle. The turns of the agents at each cycle can be randomly redistributed to break the strict ordering that is not very consistent with the reality of asynchronous operations. Classes are described in section D.

Recall that It is based on the following structures:

- **The grid**

  The grid is a rectangle (i.e., a 2D array) of identical cells. The size of the grid is limited by the quantity of RAM installed in the computer.

- **The obstacles**

  Obstacles are immobile in the grid. There is at most one obstacle per cell.

- **The agents**

  In the current version, the simulator describes at most six populations of interacting agents. The agents move in the grid. An agent cannot move into a cell already occupied by an obstacle or another agent.

F Agent cycle

F.1 Principle

The agent cycle was represented as a "black" box from **Erreur ! Source du renvoi introuvable.** to Fig. 13. Fig. 14 below details the processing executed by the agent during its cycle. However, remember that:

- Fig. 14 is incomplete because representing the whole agent cycle is complex. In particular, the agent considered here has no communication capabilities.
- Fig. 14 is **not** the real implementation, which depends on how the environment is scanned and built (see below FINE and COARSE modes and the incremental construction).

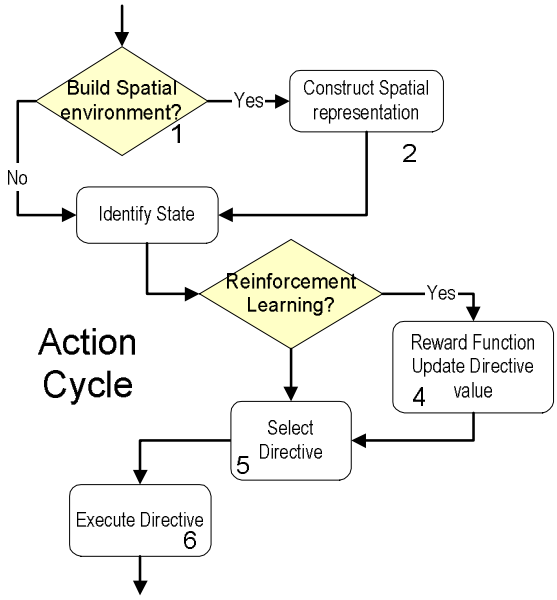


Fig. 14: Decomposition of the agent cycle in 7 steps

Whatever the mission is, the agent cycle is always similar and composed of 7 steps:

Step1 : Test to construct the spatial environment

The first step consists in testing whether the spatial environment must be constructed, as it is not needed in some applications (or some configurations). For example, if agents are not mobile, it is necessary to construct one single time the representation of the environment to locate the neighboring agents.

Steps 2 : Construction of the representation of the spatial environment:

The construction of the representation of the spatial environment consists in determining who occupies the surrounding cells within a sense radius. This spatial state depends on how is represented the space around the agent. It is important to stress that several representations of the surrounding space are possible and that several constructions are also possible. The COARSE and the FINE representations are described in chapter 8 page 127.

Steps 3 : State identification

The agents must be always able to recognize one state. The state identification (step 4 in Fig. 14) consists in testing a Boolean expression involving both the spatial environment and the state variables of the agent.

Steps 4 (optional) : Reinforcement learning processing

See section E page 162.

Steps 5 : Policy

Following the state identification, the agent chooses an action. In general, several actions are possible with different probabilities. If reinforcement learning is activated, the periodically agent updates the different agent probabilities from the comparison of its evolution resulting from the previous actions. The selection of actions represents the agent's policy (see section). The selection of actions represents the agent's policy described in chapter9 page 150.

Steps 6 : Execution of the selected action

Then, the agent executes the selected action. The concept of action is particularly fuzzy. One may distinguish between low-level and high-level actions. For instance “moving to the next cell in the northwest direction” is a low-level action. Now, “moving away from the agents of the same family” is a high-level action, which requires some additional agent processing to deduce the final low-level action. We shall denote a high-level action as a directive. Following a directive, the agent decides one or several actions and finally selects one. It is generally much simpler to specify a policy (i.e., a state automaton) in terms of directives than in terms of low-level actions. Directives and actions are described in the second manual entitled DLLs Manual.

The program must be as versatile as possible to enable changing the agent mission and within a mission to test different environment representations, different environment constructions and different policies. In this context, the programmer can customize the simulation module without rewriting most of the AI code (see Manual 3 for customization). The programmer can:

- **Define the initial distribution of obstacles** (see chapter 6 and).
- **Define the initial distributions of agents** (see the *Start Distribution* group box in Fig. 43, page 127).
- **Define the agent turn mode (synchronous versus asynchronous operation modes of agents,** see Fig. 43, page 127**)**.
- **Define the generation mode of additional agents during the simulation (**see the *Steady State Generation* group box in Fig. 43, page 127).
- **Define the environment construction mode**. The different construction modes are described in details in paragraph IB of chapter 8, page 133. We consider different incremental and non incremental modes, based on the cell scan or the agent scan.
- **Define the Environment representation**. We consider 2 representation modes: The COARSE mode and the FINE mode are described in details in paragraph IA of chapter 8, page 127).
- **Define the missions, tasks and identify actions**.

Note that the combination of several representation modes (at least 2: COARSE and FINE), of several scan modes (AGENT SCAN & various CELL SCANS, including the incremental and non-incremental construction) AND several tasks (to fulfill the mission) provides a significant flexibility in the agent behavior design.

G Thread initialization

The function `void MainTest(COREDATA* pData)` interfaces the module WIN32 with the processing thread. Concretely, clicking any button *Draw Curve*, *Add to Chart* or *Rebuild Chart* (see Fig. 43) initiates the following cycle:

- The control is transferred to the member function `void CAGNTView::StartThread()`, which begins the thread and calls the thread function `ThreadProc`, which passes a `THREADATA` pointer to `MainTest` (see paragraph *B3.2: Control transfer to start* simulation page 68). The corresponding code is displayed below.

```
void CAGNTView::StartThread()
////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////
{
      Invalidate();
      INT ThreadProc(LPVOID);      //FUNCTION PROTOTYPE
      ThreadData.bRunThread=true;
      ThreadData.bAbortThread=false;
      pWThread=AfxBeginThread(ThreadProc,&ThreadData);
      .......... etc
  .........
}

UINT ThreadProc(LPVOID pParam) (July 2003)
////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////
{
      HWND hwnd;
      void MainTest(COREDATA* pData);      //FUNCTION PROTOTYPE
   ////////////////////////////////////////////////////////////////////////////
      COREDATA* pData= (COREDATA*) pParam;
      UINT      jMessage=1;
      UINT iCounter=0;
      MainTest(pData);
      pData->bRunThread=false;
      pData->bAbortThread=false;
   ////////////////////////////////////////////////////////////////////////////
      //IMPORTANT: DO NOT REMOVE THE NEXT INSTRUCTION BECAUSE IT FORCES THE CORRECT
      //GRAPHIC UPDATE AT THE END OF THE SIMULATION
      ::SendMessage(pData->m_ViewhWnd,WM_PAINT,0,0);
   ////////////////////////////////////////////////////////////////////////////
   //REPAINT THE PROPERTY PAGES TO UPDATE ALL CONTROLS IF THEY ARE OPEN ON THE SCREEN
      CMainFrame* pTop=(CMainFrame*) AfxGetApp()->m_pMainWnd;
       if (pTop->m_pPropFrame!=NULL) {
            hwnd=pTop->m_pPropFrame->m_pModelessPropSheet->m_Page1.m_hWnd;
            ::SendMessage(hwnd,WM_PAINT,0,0);
            hwnd=pTop->m_pPropFrame->m_pModelessPropSheet->m_Page2.m_hWnd;
            ::SendMessage(hwnd,WM_PAINT,0,0);
            hwnd=pTop->m_pPropFrame->m_pModelessPropSheet->m_Page3.m_hWnd;
            ::SendMessage(hwnd,WM_PAINT,0,0);
            hwnd=pTop->m_pPropFrame->m_pModelessPropSheet->m_Page4.m_hWnd;
            ::SendMessage(hwnd,WM_PAINT,0,0);
            hwnd=pTop->m_pPropFrame->m_pModelessPropSheet->m_Page5.m_hWnd;
            ::SendMessage(hwnd,WM_PAINT,0,0);
      }
      ////////////////////////////////////////////////////////////////////////
      //CODE TO OPEN THE MAIN WINDOW WHEN ICONIZED AT THE END OOF THE COMPUTATION
      if (::IsIconic(pTop->m_hWnd)) {
            if(::MessageBox(NULL,"End of Calculation.\n    Display data?",
```

```
                        "FROM AGENTS",
                        MB_YESNO | MB_ICONEXCLAMATION)==IDYES)
                pTop->ShowWindow(SW_NORMAL);
   }
   ////////////////////////////////////////////////////////////////////////////
      return 0;
}
```

- `MainTest` is executed and controls the simulation session. Fig. 12 showed a partial representation of the flowchart of `MainTest`. The flowchart in Fig. 15 includes additional service tasks in the main iteration loop required to integrate the AI code in the application. These services comprise:
  1- **Thread execution control**: this module controls the thread abortion, possibly requested by the user
  2- **Storage of terrain to disk**.
  3- **Interpreter calculation for the module GRAPH**: `Maintest` passes arguments to `void DataProcessForChart` to calculate the function plotted by GRAPH or GDI (see the previous chapters)
  4- **Generation of new agent during the simulation.**
  5- **Emission of private messages** to update the graphic display (terrain or 2D plot of user-defined functions)

Fig. 15 also shows that the AI code is not in `Maintest` but in external routines which are called depending on the selected scan mode: `Cell Scan` or `Agent Scan`.

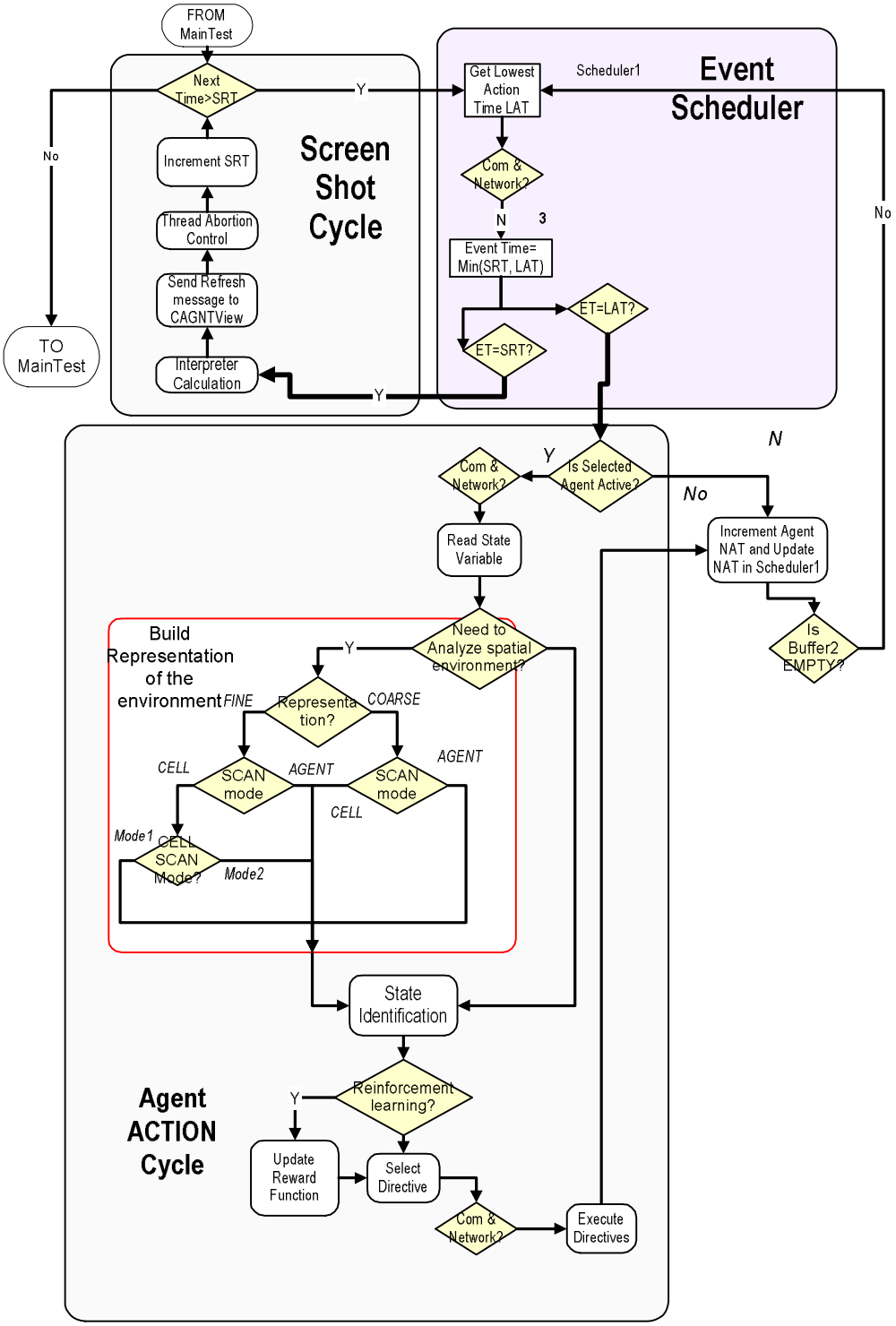


Fig. 15: Flowchart of the function **`MainAsynchronous`** for a non-communicating agent

G.1 DLL: Function calls in the agent cycle

It is important to know "who calls who", i.e., how the control is transferred to start a simulation session. The script below shows the main calls of functions when the agent cycle is imported from a DLL.

```
MainTest
    MainTestAsynchronous
        BuidlLookUpTable
        #include "EiCInitialization.cpp"
        NetworkMode
            CellScanNet
                              DllFINECellScanNetwork
            AgentScanNet
                         ..................................
        ActionMode
            BuildEnvACTION
            FindState
            CELLScan
                 DllCOARSECellScan
                             ..................................
                             ..................................
                 DllFINECellScan
                      DllFINECellScanMode1
                           ScanFINECELLClose
                                #include "CellProcAction.cpp"
                                     FINEStoreInArray
                                     PolicyFunction
                                     UpdatePosition
                           ScanFINECELLRing
                                #include "CellProcAction.cpp"
                                     FINEStoreInArray
                                     PolicyFunction
                                     UpdatePosition
                           DLLFINECELLFindState
                      DllFINECellScanMode2
                           ScanFINECELLClose
                           ScanFINESAroundObjects
                                DLLFINECELLCloseScan
                                #include "CellProcAction.cpp"
                                     FINEStoreInArray
                                     PolicyFunction
                                     UpdatePosition
                      ScanFINECELLRing
                           #include "CellProcAction.cpp"
                                FINEStoreInArray
                                PolicyFunction
                                UpdatePosition
                      DLLFINECELLFindState
            AGENTScan
                 DllFINEAgentScan
                  ..................................
                  ..................................
        #include "EiCExecution.cpp
            ..................................
            ..................................
    MainTestSynchronous
```

Script 11: Function calls in the agent cycle

Chapter 3

Interface: MFC classes

This chapter describes the files in the module WIN32 involved to construct the program interface.

As previously stressed, MASS is a MFC-based application written with VisualC. The *solution* file (using the terminology of VisualC7) is (typically) entitled Dec08.net\MASS\AGNT.sln for the code saved on December 8th. WIN32 is the main module as it could work (of course with reduced functionalities) without the other modules when it is impossible conversely.

A Base Classes

WIN32 includes the default classes automatically generated by VisualC and derived from the usual basic MFC classes, namely:

A.1 class CAGNTApp : public CwinApp

CAGNTApp is the top class of MASS. The header AGNT.h includes the identifiers to send private messages, and also the events declaration necessary to synchronize the accesses of threads to critical sections

```
////////////////////////////////////////////////////////////////////////////
//      PRIVATE MESSAGES USED BY THE THREAD TO COMMUNICATE WITH THE PARENT CAGNTView INSTANCE
#define WM_DISPLAY_ITER         (WM_USER+120)      //USER-DEFINED MESSAGE
#define WM_DISPLAY_POPNB        (WM_USER+121)      //USER-DEFINED MESSAGE
#define WM_UPDATE_DISPLAY       (WM_USER+122)      //USER-DEFINED MESSAGE
#define WM_END_THREAD           (WM_USER+123)      //USER-DEFINED MESSAGE
#define WM_SAVE_PLAYGROUND      (WM_USER+124)      //USER-DEFINED MESSAGE
////////////////////////////////////////////////////////////////////////////
//PRIVATE MESSAGES USED BY THE CParamPage TO COMMUNICATE WITH THE PARENT CParamSheet
#define WM_RUN_SESSION        (WM_USER+130)   //USER-DEFINED MESSAGE
#define WM_APPLY_BUTTON       (WM_USER+131)   //USER-DEFINED MESSAGE
```

```
#define WM_SAVE_DEFAULT      (WM_USER+132)   //USER-DEFINED MESSAGE
#define WM_SWITCH_PAGE2      (WM_USER+133)   //USER-DEFINED MESSAGE
#define WM_SWITCH_PAGE3      (WM_USER+134)   //USER-DEFINED MESSAGE
#define WM_SWITCH_PAGE6      (WM_USER+135)   //USER-DEFINED MESSAGE
#define WM_SWITCH_POLICY     (WM_USER+136)   //USER-DEFINED MESSAGE
#define WM_SWITCH_COLORMODE  (WM_USER+137)   //USER-DEFINED MESSAGE, USED By PARAMPAGE2
#define WM_CHANGE_AGENTCOLOR (WM_USER+138)   //USER-DEFINED MESSAGE, USED By PARAMPAGE2
#define WM_OPEN_DLL          (WM_USER+139)   //USER-DEFINED MESSAGE, USED By PARAMPAGE6
////////////////////////////////////////////////////////////////////////////
//PRIVATE MESSAGES USED BY EiC ERROR FUNCTION TO ASK MAINFRAME TO REOPEN THE EDITOR
#define WM_REOPEN_EDITOR      (WM_USER+140)      //USER-DEFINED MESSAGE
////////////////////////////////////////////////////////////////////////////
//PRIVATE MESSAGE TO SAVE TO DATA IN THE MISSION PARAMETERS DIALOG
#define WM_SAVE_MISSION_PARAM (WM_USER+145) //USER-DEFINED MESSAGE
////////////////////////////////////////////////////////////////////////////
//PRIVATE MESSAGES USED TO CONTROL THE REPLAY OF WMF IMAGES
#define WM_PLAY_WMF      (WM_USER+148)      //USER-DEFINED MESSAGE
////////////////////////////////////////////////////////////////////////////
//PRIVATE MESSAGES USED BY THE DRAFT MODULE
#define WM_OK_OBJECT (WM_USER+160)            //USER-DEFINED MESSAGE
////////////////////////////////////////////////////////////////////////////
```

Script. 2

```
class CAGNTApp : public CWinApp
{
public:
      virtual BOOL PreTranslateMessage(MSG* pMsg);
      HANDLE m_hSafe1;
       HANDLE m_hPAUSE; //HANDLE FOR EVENT AND SYNCHRONISATION OF THE THREAD
       HANDLE m_hSTEP;  //HANDLE FOR EVENT, STEP BY STEP CONTROL OF THE THREAD
      CString MASSDir;
      CString m_AcrobatReaderpath;
      void InitDefaultData();
      HWND      hActiveDlg;           //HANDLE OF THE ACTIVE DIALOG BOX
      CAGNTApp();
      void ChangeSystemColors();
      CMultiDocTemplate* pDocTemplate;
      void OpenPDF_File(CString PDF_File);
      //WARNING WARNING WARNING WARNING WARNING WARNING WARNING
#define FREEPARAMNB 8        //NUMBER OF PARAMETERS THAT CAN BE MODIFIED BY THE CORE
                             //IF YOU MODIFY FREEPARAMNB HERE, MODIFY IT IN GLOBAL.h
#define FREEPOLICYPARAMNB 6  //NUMBER OF PARAMETERS THAT CAN BE MODIFIED BY THE CORE
                             //IF YOU MODIFY FREEPOLICYPARAMNB HERE, YOU MUST MODIFY IT
                             //IN GLOBAL.h
.. .. ..
.. .. ..
};
```

A.2 class CMainFrame : public CMDIFrameWnd

A.3 class CChildFrame : public CMDIChildWnd

A.4 class CAGNTDoc : public ColeDocument

A.5 class CAGNTView : public CformView

As MASS is a multidocument application (MDI), it may contain several instances of the CAGNTView/CAGNTDoc classes, explicitly, one per created simulation window. Each CAGNTView instance contains a set of simulation variables declared in the class header CAGNTView.h. The variables and array shared with the simulation thread are grouped together in the instance ThreadData of the structure COREDATA. These variables comprise:

- The parameters necessary to run a simulation (size of the terrain, number of agents, condition of agent generation, variables to define the environment construction mode, etc…).
- Data to control the execution of the simulation thread and data updated by the simulation thread, (used by CAGNTView) to trace graphically the evolution of agent populations during the simulation.

The full declaration the structure COREDATA is shown below. Member variables described in the previous paragraph are grayed. Most parameters in section 1 of the header are used to define how the agent constructs its environment and how it scans the memory.

```
struct COREDATA
{
////////////////////////////////////////////////////////////////////////////
short iDY;                  //SHIFT
////////////////////////////////////////////////////////////////////////////
//SECTION 1: AGENTS
AGENT*      Agent[AGENTTYPENB];
short         iAInitNb[AGENTTYPENB];       //INITIAL NUMBER OF AGENTS
short         iAMAXNb[AGENTTYPENB];        //MAX NUMBER OF AGENTS RESERVED IN MEMORY
AGENT0*     Agent0;
AGENT1*     Agent1;
AGENT2*     Agent2;
AGENT3*     Agent3;
AGENT4*     Agent4;
AGENT5*     Agent5;

BOOL     bSynchronous;
Int      iGenMode[AGENTTYPENB];  //INITIAL AGENT GENERATION MODE (RANDOM,LEFT,RIGHT..)
short    iAGenNb[AGENTTYPENB];   //NB OF AGENTS GENERATED PER ITERATION
int      iSSMode[AGENTTYPENB];   //STEADY-STATE AGENT GENERATION MODE(RANDOM,LEFT,RIGHT,)
char*    AgentMode[AGENTTYPENB]; //AgentMode[i][j]: STATE OF AGENT OF TYPE i & RANK j
short    iRadiusNb[AGENTTYPENB]; //NB OF RADIUSES AROUND AGENT. NOW: iRadiusNb=2
short*   Radius[AGENTTYPENB];    //RADIUSES AROUND EACH AGENT
int      iSectorNb[AGENTTYPENB]; //NB OF ANGULAR SECTORS TO DESCRIBE FAR ZONES
short    iAScanMode[AGENTTYPENB];//0:SCAN ZONES; 1:SCAN AGENTS
short    iAEnvironMode[AGENTTYPENB];//0:COARSE REPRESENTATION; 1: FINE REPRESENTATION
COLORREF AgentColor[AGENTTYPENB];   //COLOR OF AGENTS
short    iAStrategy[AGENTTYPENB];   //AGENT POLICY
BOOL     bMissionDLL[AGENTTYPENB];
BOOL     bDefaultStraightMove[AGENTTYPENB];      //if TRUE, STRAIGHT MOVE IS DEFAULT
////////////////////////////////////////////////////////////////////////////
//SECTION 2: OBSTACLE
short     iObst1Nb;    //NB OF TYPE1 OBSTACLES IN THE TERRAIN
short*    ObstacleX;   //X-COORDINATE OF OBSTACLES CALCULATED FOR 2D GAPHICS
short*    ObstacleY;   //Y-COORDINATE OF OBSTACLES CALCULATED FOR 2D GRAPHICS
OBSTACLE* Obstacle1;   //OBSTACLES OF TYPE1 IN THE TERRAIN
int iGenModeObstacle1; //INITIAL GENERATION MODE OF OBSTACLES (RANDOM=0, FROM A FILE=1,..)
COLORREF ObstacleColor;         //COLOR OF obstacles
////////////////////////////////////////////////////////////////////////////
//SECTION 3: TERRAIN
short      XDim;          //X DIM OF THE TERRAIN
short      YDim;          //Y DIM OF THE TERRAIN
CELL*      Cell;          //THE TERRAIN IS A RECTANGULAR ARRAY OF CELL OBJECTS
```

```
bool      bXtorusMode;    //if TRUE, NO X BORDER, CYCLIC CONDITION
bool      bYtorusMode;    //if TRUE, NO Y BORDER, CYCLIC CONDITION
short      iteratNb;      //
bool      bSaveTerrainToDisk;
CString      TraceFileName;
short     iTraceSavePeriod;
int      iAgentSizeInWMF;
////////////////////////////////////////////////////////////////////////////
//SECTION 4: 2D-GRAPHICS
bool      bTracing;            //true: TRACE THE AGENTS IN THE 2D GRAPHICS
bool      bDisplay;            //true: DISABLE 2D GRAPHICS
////////////////////////////////////////////////////////////////////////////
//SECTION 5: THREAD CONTROL
CString     Title;              //CVIEW TITLE
HWND        m_ViewhWnd;         //HANDLE OF THE VIEW (TO RETURN MESSAGES)
HWND        m_TopFRMhWnd;       //HANDLE OF THE TOP FRAME (TO DETECT ICONIZED STATE)
bool        bRunThread;         //DEFAULT= true; IF false: STOP THREAD EXECUTION;
bool        bStepThread;        //STEP BY STEP MODE
bool        bAbortThread;       //FALSE=STOP; TRUE=RUN
bool        m_hWaitTrhead;      //TO SUSPEND THE TREAD (??? OBSOLETE?)
HANDLE      m_hEndTrhead;       //SYNCHRONIZATION HANDLE TO RETURN TO MAIN THREAD
int         m_iTopicsNb;        //THE INDEX OF THE TOPICS UNDER PROCESSING
int         m_iThreadPriority;
bool        bInfiniteRUN;       //true: INFINITE NUMBER OF ITERATIONS
bool        bRandomizeTour;     //true: RANDOMIZE AGENTS TOURS AT  EACH ITERATION
int        iDelayPerItera;      //DELAY ADDED TO SLOW DOWN THE MAIN LOOP EXECUTION
////////////////////////////////////////////////////////////////////////////
//SECTION 6: 2D GRAPH
float* XData;            //FOR QCWChart
float* YData;            //FOR QCWChart
int iChartPtNb;          //NB OF POINT FOR XData & YData ARRAYS
////////////////////////////////////////////////////////////////////////////
//SECTION 7: PARSER
CString       EiC_CODE;      //CODE FOR THE INTERPRETER
////////////////////////////////////////////////////////////////////////////
//LIST OF GRAPHIC OBJECTS DEFINING THE OBSTACLE DRAFT
CLine*       Line;         //ARRAY OF LINES DRAWN IN THE WINDOW
int          iLineNb;      //NB OF DRAWN LINES
CRectangle*  Rect;         //ARRAY OF RECTANGLES DRAWN IN THE WINDOW
int          iRectNb;      //NB OF DRAWN RECTANGLES
CBrokenLine* BrokLine;     //ARRAY OF BROKEN LINES DRAWN IN THE WINDOW
int          iBrokLineNb;  //NB OF DRAWN BROKEN LINE
CPolygone*   Polygone;     //ARRAY OF POLYGONES DRAWN IN THE WINDOW
int          iPolygoneNb;  //NB OF DRAWN POLYGONES
////////////////////////////////////////////////////////////////////////////
};
```

B Interface classes

B.1 Review

We list here several additional classes included in the module WIN32 to enrich the graphic interface and to make as simple as possible the interaction of the user with the application:

- **`class CBmpDialog : public CfileDialog`**.

  This class is an extension of the Microsoft CfileDialog class, which integrates a Metafile (WMF) viewer in the OpenFile Box. This functionality is particularly useful to preview the obstacles configuration before loading a file.

- **`class CcolorArray`**.

  This simple class simplifies the use of RGB colors.
- **`class CParamFrame : public CminiFrameWnd`**.
- **`class CParamSheet : public CpropertySheet`**.

  This class is the parent of the pages (CparamPage1, CparamPage2,.. until CparamPage9) to setup the parameters of the simulation session.
- **`class CParamPage1 : public CpropertyPage`**

  This class controls the terrain parameters, the obstacles, the general execution of the program (number of iterations,..), etc..

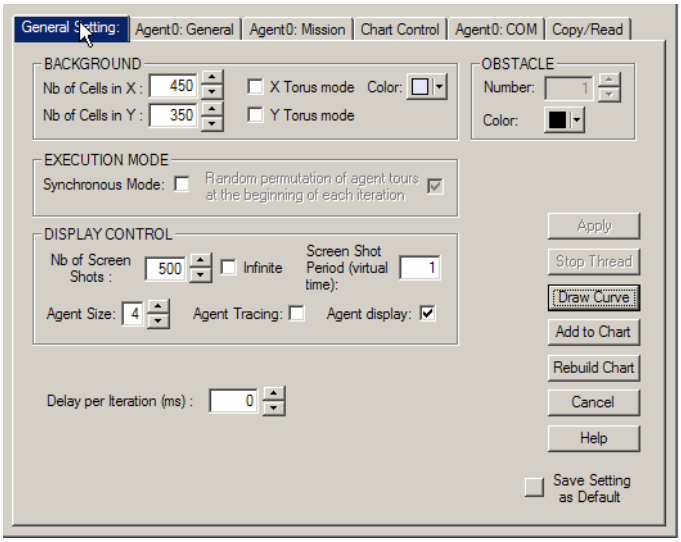


Fig. 16: Property Page 1 with the 3 buttons "Draw Curve", "Add to Chart, and "Rebuild Chart" to start a simulation session.

- **`class CParamPage2 : public CpropertyPage`**.

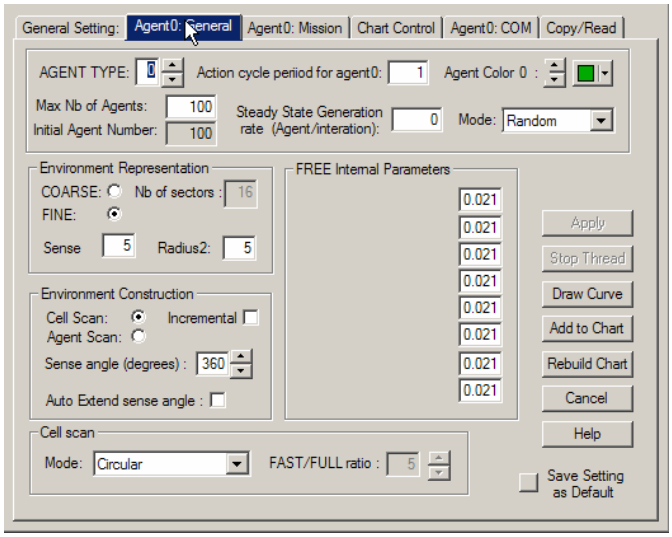


Fig. 17: Property Page 2 with the 3 buttons "Draw Curve", "Add to Chart, and "Rebuild Chart" to start a simulation session.

This property page is also described in paragraph *Recall* that It is based on the following structures:

- **The grid**

  The grid is a rectangle (i.e., a 2D array) of identical cells. The size of the grid is limited by the quantity of RAM installed in the computer.

- **The obstacles**

  Obstacles are immobile in the grid. There is at most one obstacle per cell.

- **The agents**

  In the current version, the simulator describes at most six populations of interacting agents. The agents move in the grid. An agent cannot move into a cell already occupied by an obstacle or another agent.

Agent page 53 and Fig. 43 page 127.

- **`class CparamPage3 : public CpropertyPage`**.

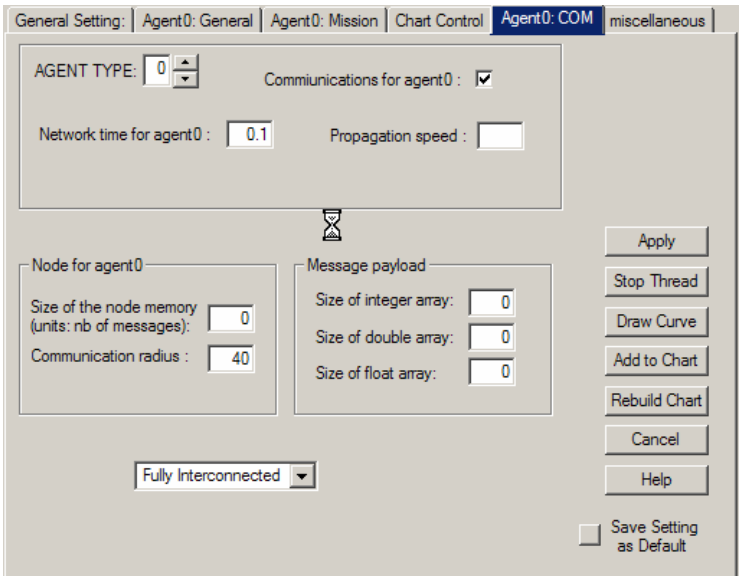


Fig. 18: Property Page 3 for communications. I includes the 3 buttons "Draw Curve", "Add to Chart, and "Rebuild Chart" to start a simulation session.

- **`class CparamPage4 : public CpropertyPage`**.

  This class contains the syntax-colored editor, which is coupled to the interpreter (see chapter 5, page 84). This functionality is included to enable customization of the functions plotted at run time in the module GRAPH

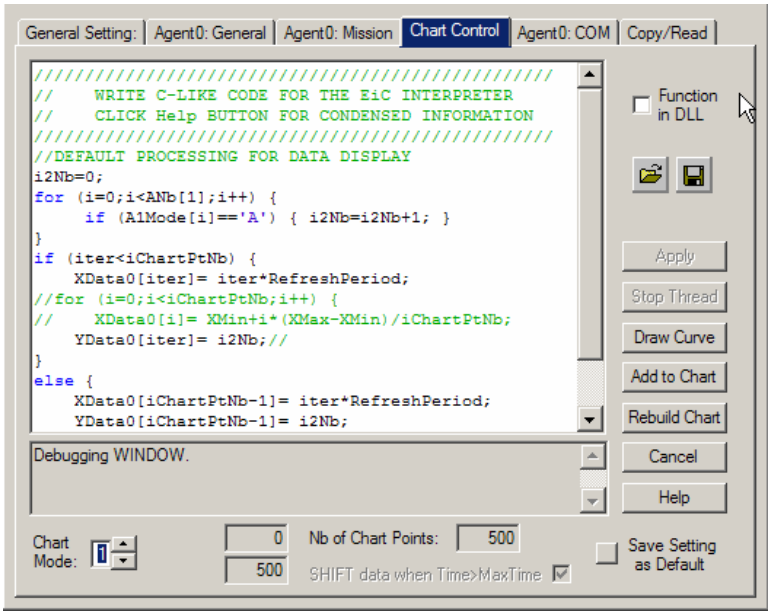


Fig. 19: Property Page 6 with the 3 buttons "Draw Curve", "Add to Chart, and "Rebuild Chart" to start a simulation session.

- **`class CparamPage5 : public CpropertyPage`**.
- **`class CparamPage6 : public CpropertyPage`**.

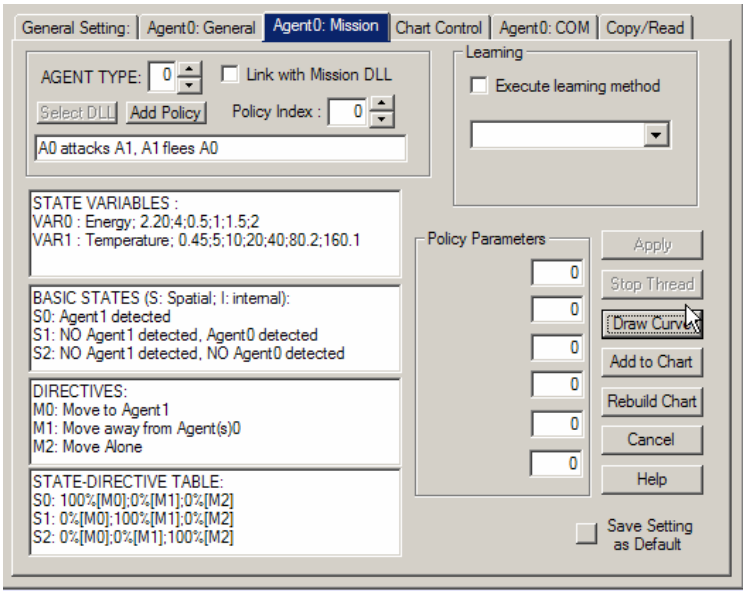


Fig. 20: Property Page 6 with the 3 buttons “Draw Curve”, “Add to Chart, and “Rebuild Chart” to start a simulation session.

- **`class CDialogBarEx : public CdialogBar.`**
- **`class CMyDialogBar : public CdialogBarEx`**.

  These classes extend the default CDialogBar class by providing functionality of initialising the dialog bar and direct access to the control via their ID using the function DX_Control(CDataExchange* pDX, int nIDC, CWnd& rControl).
- **`class CSplashWnd : public CWnd`**.

  Simple class to display a splash window at application startup.
- **`class CNumSpinCtrl : public CspinButtonCtrl`**.

  Simple class defined to extend spin control to real numbers.

B.2 Parameters management in the property pages

Most parameters controlling the simulation sessions (stored in the structure `ThreadData`) are adjustable in the 6 property pages `CParamPage1, CparamPage2, etc..` defined in the previous paragraph, which are members of the class CParamSheet : public CpropertySheet. In this context, it is simpler to manage all pages from their common parent, i.e., from `CParamSheet`. One reason to use this central control is that `CParamPage2` and `CParamPage6` display the parameters of the agent selected by the agent type spin control (see Fig. 17 page 64). Thus, depending on the agent selection, CParamPage2 and CParamPage6 display different parameters and it is simpler to keep track of these parameters in tables in `CParamSheet`, which monitors the display of the different ParamPage.

It results from this centralized supervision of the agent parameters that many controls in ParamPage2 and ParamPage6 send private messages to ParamSheet, which processes the relevant actions. All private messages are declares in CAGNTApp.h, see Script. 2page 61 (27 Nov 2003):

For instance, the message WM_SWITCH_PAGE2, is sent by ParamPage2 to ParamSheet when the users switch the agent type with the agent spin control. ParamPage2 sends the message to its parent with the standart WIN32 function:

```
::SendMessage(GetParent()->m_hWnd,WM_SWITCH_PAGE2,iAType,iOldAType);
```

B.3 Function calls

B3.1 Control transfer to change simulation parameters

To change simulation parameters prior to beginning a simulation, the user must open the parameter sheet by clicking the item Params in the application menu (see **Erreur ! Source du renvoi introuvable.**). Then:

- The control is transferred to the active instance of CAGNTDoc which executes its member function void CAGNTDoc::OnParamMenu().
- This function invokes void CMainFrame::OnProperties(), which calls void CParamSheet::UpdateParamSheet(). The role of this function consists in updating the contents diplayed in the paramPage, i.e., in copying the parameters of the active instance of CAGNTView to the member variables of the property pages, which therefore displays the simulation parameters of the selected window for further modification by the user. Fig. 16 displays the property page1 of the property sheet.

B3.2 Control transfer to start simulation

The user starts a simulation session by clicking one of the following buttons: “Draw Curve”,, “Add to Chart” or “Rebuild Chart”, in the active property page. Then:

- The active property page sends a private message WM_RUN_SESSION to the property sheet which executes the function CParamSheet::OnRunSession. Remember that the property sheet is the parent window of all property pages. Thus, the advantage of transferring the control to the property sheet is that all variables defined in the property pages are easily accessible. OnRunSession conducts 3 actions:

  4) It calls bool CParamSheet::CheckParams() to check that all parameters updated in the property pages are correct, i.e., in the admissible limits .

  5) If it is, it calls void CParamSheet::SaveAndRebuildAll(), which calls CParamSheet::TransferPage1ParametersToCOREDATA, then CParamSheet::TransferPage2ParametersToCOREDATA, and so on to copy the member variables of the property pages to the active CAGNTView instance (remember that MASS is a MDI application) and to update the dimension of the data arrays used to trace the simulation. For instance, the code of CParamSheet::SaveParams() below, shows the section to update the agent populations. pData is a pointer to the structure COREDATA.

```
for (i=0;i<AGENTTYPENB;i++) {
   delete [] pData->AgentMode[i];
   pData->AgentMode[i]= new char[pData->iAMAXNb[i]];
   delete [] pData->Agent[i];
   pData->Agent[i] = new AGENT[pData->iAMAXNb[i]];
```

  etc…

6) Then, it calls the function `CAGNTView::StartThread() of the active` instance of `CAGNTView`, which initiates and launches the simulation thread.

B.4 Code to add simulation parameters to the interface

We assume that the reader is familiar with the environment development of VisualC. We consider an example to show how to add one simulation parameter. This parameter must have an edit box in the interface and must be declared in `COREDATA` to be used by the simulation thread. We assume that a new integer variable iTest must be added to control the simulation execution.

- STEP 1: Add a button, or an edit control (of any other resource) to a property page, say for instance to page4. We assume that the ID of this control will be `ID_TEST` in the resources associated to property page4.
- STEP2: Run the class wizard of VisualC and add the member variable (for instance denoted m_iTest) to CparamPage4. Thus, m_iTest is associated to the resource `ID_TEST` of the property CParamSheet::page4.
- STEP3: Edit the file Threaddata.h and add the variable (for instance denoted iTest) to the `COREDATA` structure. It is necessary to declare this variable to copy the value of the property page variable CparamPage4::m_iTest to the `COREDATA`, that is transmitted via a pointer to the Threadfunction. Note that it is particularly simple to use a single name `m_iTest` to represent the 2 different variables `COREDATA::m_iTest` and `CparamPage4::m_iTest` associated to the same parameter.
- STEP4: Edit void CAGNTView::OnInitialUpdate() and add the initialization code of the variable iTest. For instance, if the initial value is 3, add:

```
ThreadData.iTest=3;
```

- STEP5: Edit CParamSheet::CparamSheet add add the next code to transfer the value from the active window to the property page

```
MPage3.m_iTest=pView->ThreadData.iTest
```

- STEP6: Add the same code to void CParamSheet::UpdateParamSheet()
- STEP7: Edit void CParamSheet::SaveParams() and add the following code to transfer the value from the page to the active view prior to running a simulation

```
pView->ThreadData.iTest=MPage3.m_iTest
```

- **STEP8**: Add the same code to `CParamSheet::OnApplyButton`

B.5 Code to store parameters in registries

It is possible to store in the Windows registries most parameters that are adjustable in the property pages (`Cparampage1, Cparampage2`, etc..). The values of parameters saved in the registries become the default initial values for the next run of MASS.

Code to write parameters in registries:

To save the parameters in all property pages, click the small square button (entitled “save settings as default”) in the right bottom corner. Clicking this button transfers the control to the following member function of `CParamSheed` :

```
LRESULT CParamSheet::OnSaveParamsAsDefault(WPARAM wParam,LPARAM lParam)
```

This function extensively uses the Win32 routines `WriteProfileInt` and `WriteProfileString` to save data in the registries. Perhaps, the most interesting feature of this code is the systematic call to the following macro:

```
////////////////////////////////////////////////////////////////////////
#define SAVEINREGISTRY(n,String,param)
\
      if (n==0)                                                        \
            AfxGetApp()->WriteProfileInt("PROP PAGE2",String,m_Page2.param);   \
      else if (n==1)                                                   \
            AfxGetApp()->WriteProfileInt("PROP PAGE3",String,m_Page3.param);   \
      else ::MessageBox(NULL,"CODE NOT WRITTEN","FROM SAVEINTEGISTER",MB_OK);
////////////////////////////////////////////////////////////////////////
```

The macro does not check the passing parameters and uses the member variables `m_Page2`, `m_Page3` of `CParamSheet.`

Code to read parameters in registries:

Registries are read when the View is constructed to define default initial values of parameters. The code to read the registries is in `void CAGNTView::OnInitialUpdate()`. It rests essentially to the call of the functions `GetProfileInt` and `GetProfileString`.

Chapter

4

Agent properties calculation at runtime

The CORE includes a C - like interpreter (coupled to a syntax-colored editor) to calculate and display at runtime any user-defined agent properties. This appraoch enables customization of the function plotted by the module GRAPH, without additional code compilation.

Revisions: 080801: Shift of the Eic interpreter in a DLL (JHC)

One essential and fundamental facility of the CORE is to make it possible to graphically plot any property of the agents during the temporal evolution of the populations. It is admitted that you already read the chapter entitled "Display & management of data" in the Tutorial of MASS (see the file Tutorial.pdf). MASS includes two solutions to calculate and plot data at runtime:

1) The solution discussed in this chapter consists in calculating the agent property (i.e., any function defined from the agent variables) with an interpreter because it enables changing at runtime the functions (plotted by the module GRAPH, see next chapter) without recompiling the code. We call this approach the interpreter approach. However it has some intrinsic limitation as it does not slow down the execution speed of MASS so long as the time needed to calculate the plot functions (with the interpreter) is a small fraction of the time devoted to calculating the agent dynamics through the compiled code executed in Thread II (see Fig. 2 in page 15).

2) Another solution consists in defining the property function in the DDL (so-called DLL approach). In that case the user-defined code defining the agent function must be inserted in the function `GraphFunc` of the agent 1. The benefice of this solution is that the property calculation is much faster (as the function code in compiled in the DLL). The price to pay is less interactivity in the definition of the property.

A Interpreter approach

A.1 Selecting an existing interpreter

Embedding an third-party interpreter in a compiled application is a tedious task. Why? The main issue consists in finding a solution to make that the interpreter shares data with the host, or in other words, that it is possible transfering data from the compiled code to the interpreter and conversely.

Several free C interpreters were available on the WEB in 2002 (for instance: *Cint*, *CH*, *CSL*, *EiC*, *ICI*, *Quincy*, *RuntimeC*, *SAScript*, *Seer*, etc..). However, this diversity was fallacious because most interpreters were either not documented, or written with old C code that VisualC could not compile, or not fully implemented (sometime *float* and *double* types were not defined), etc, etc.. Following many tedious tests, we finally chose *EiC*, because:

1) It simply enables exchanging data with the host;

2) It is documented;

3) It is a freeware under the Artistic license. *EiC* code and documentation are available from the WEB site: http://www.kd-dev.com. This application was written by Edmond J. Breen.

EiC (as most interpreters) originally worked in a DOS-like edition window. Thus, we developed a syntax-colored editor (for C-like code) displayed in Fig. 21 with the default function, which calculates the number of active agents `iAType=1`.

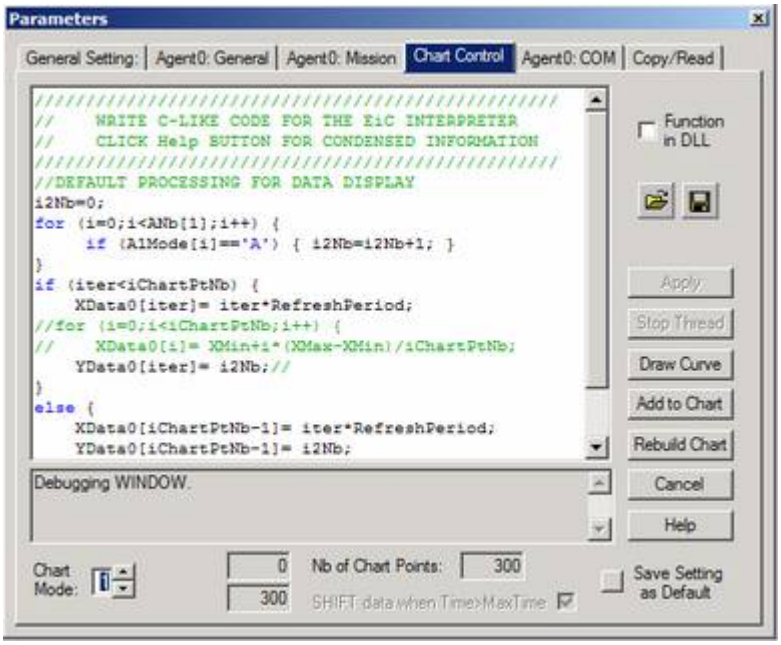


Fig. 21: Edition window in the “Graph Control” property page

Note that the control of the interpreter (in particular the edition window shown in Fig. 21) is located in the "Chart Control" property page. It parses the code (i.e., the string in the edition window) to calculate the functions. Concretely, the implementation of EiC in MASS is as follows: The user can

customize the function plotted in the Chart Mode (see the User Manual) by modifying the function[10] edited in the property page entitled *Chart Control*. Recall that EiC is a C interpreter, not a C++ interpreter. The user must write C-like code, following the prescription detailed in the EiC manual [].

On run (i.e., when depressing *Draw Curve*, *Add to Chart* or *Rebuild Chart*):

- The script written in the edition window is saved and declared as `CString EiC_Code` in section VII of the `COREDATA` structure (see the `COREDATA` structure in paragraph A.5, page 62).
- MASS begins the work thread and calls the main function `void MainTest(COREDATA* pData)`, which invokes the interpreter as represented the red strings in Fig. 22 page 74.
- EiC calculates the plot function(s) defined by `EiC_Code`. Data calculated by EiC are transferred to the GRAPH module.

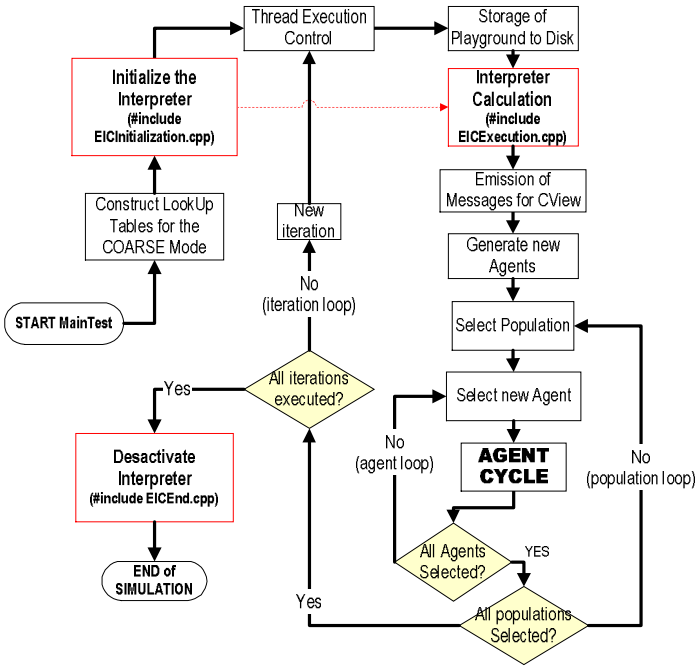


Fig. 22: Functional blocks in **`MainTestSynchronous`**. EiC is embedded through 3 #include instructions represented in the red color.

How writing functions is extensively discussed in the next section (see page 84). We only discuss in this chapter how the interpreter is integrated in MASS.

The functions written in the edition window must call the the variables of the compiled code, which are used to display data in the graph window.

[10] *The original default function calculates the number of active type-1 agents. However, by saving the editor window to the file default.eic, it is possible to redefine the default plot function.*

A.2 Sharing data between the host and the interpreter

As previously stressed, the main issue to embed any stand-alone interpreter in an application consists in finding a solution to make that the interpreter shares data with the host, or in other words, that it is possible transfering data from the compiled code and conversely or to read the memory space of the application. Suppose for instance that at run time, MASS constructs the following array to calculate the agent dynamics:

Eq. 2
```
int* AgentX = new int [iAgentNb];
```

As this array belongs to the memory space of MASS, it is not accessible to the interpreter defined as a stand-alone independent application. To move around the difficulty, *EiC* functions are compiled with MASS and enable building a private array (with same type and dimension), which points to `AgentX`, enabling data exchange with the compiled data. *EiC* documentation explains how to define arrays pointing to compiled arrays.

This procedure is simple but particularly nasty when one asks *EiC* to construct arrays with dimension adjusted at runtime to the array defined in MASS as in Eq. 2. Thus, we wrote several simple functions to encapsulate this operation.

Function void EiC_BuildInt(char*,int*)

This function constructs an integer for the interpreter.

Example : To create an integer `iX` in *EiC* that points to `iCX` in the compile code write:

```
int iCX=1;     // DEFINITION OF iCX IN THE COMPILE CODE
…
…
EiC_BuildInt("iX",&iCX);//POINTER TO iCX FOR THE INTERPRETER[11]
```

Any operation of EiC on `iX` modifies the compiled variable `iCX`.

Function void EiC_BuildIntArray(char*,int,char*,int, int*)

This function constructs an array of integers for the interpreter.

Example 1: To create an array of integers entitled “A3X” in EiC pointing to the integer array `MyArray` of dimension `iDim` in the compiled code, write:

```
EiC_BuildIntArray("A",3,"X",iDim,MyArray);
```

Note that `iDim` is a integer, not a constant, so that EiC constructs an array with the dimension adjusted at run time.

Example 2: To create several arrays of integers in EiC entitled “A0X” of dimension iDim[0], “A1X” of dimension iDIm[1], “A2X” of dimension iDim[2], until “ANX” of dimension iDim[N] (where N is an integer) from the arrays of integers MyArray[I] with 0<=I<N, write:

```
for (i=0;i<N;i++) EIC_BuilIntAray("A",i,"X",iDim[i],MyArray[i]);
```

With this code, EiC manipulates the element `A0X[k]` which points to the element `MyArray[0][k]`, `A1X[k]` which points to the element `MyArray[1][k]`, etc..

[11] Internally, this function constructs the string `MyStr=" int iX @ %ld"` and calls `EiC_parseString(MyStr,&iCX).`

The use of the following function is similar to that of `EiC_BuildIntArray`

Function void EiC_BuildDoubleArray(char*,int,char*,int, double*)

Function void EiC_BuildFloatArray(char*,int,char*,int, float*)

Function void EiC_BuildBoolArray(char*,int,char*,int, bool*)

A.3 Practical integration of the interpreter EiC in MASS

EiC is embedded in the function `void MainSynchronous(COREDATA* pData)`, as represented in Fig. 22[12] page 74. The integration is achieved via the three following `include` instructions:

```
#include "EiCInitialization.cpp"
#include "EiCExecution.cpp"
#include "EiCEnd.cpp"
```

A3.1 #include "EiCInitialization.cpp"

Prior to invoking *EiC*, the code in `\PARSER\EiCInitialization.cpp` (see Script 12 below) constructs several compiled arrays and forces *EiC* to construct several arrays pointing to these compiled arrays. **The role of these arrays is to enable reaching agent parameters in the interpreted code** to freely define the functions to plot in the graph window! Explicitly,:

- The code creates the (compiled) arrays `AX[0]` of dimension `iAMaxNb[0]`, `AX[1]` of dimension `iAMaxNb[1]`, `AX[2]` of dimension `iAMaxNb[2]`… (see the section highlighted with the blue bar 1). Note that these arrays are allocated here in `EiCInitialization.cpp`, then initialized with the agent positions in `EiCExecution.ccp` (see Script 13). The array `AX[0]` is a one-dimension array, which stores the X position of agents, through the initialization: `AX[0][i]=Agent[0][i].X`! **Now, why this crazy duplication of data**? Because EiC is a C interpreter and not a C++ interpreter! So, it cannot directly access the member variables of the Agent classe `Agent[0][i].X`. It is necessary to copy the agents positions { `Agent[0][i].X` | `0≤i< iAMAXNb[i]`} in a regular C array, and in a second step, to create a pointer in EiC, which points to the base address of this array. This duplication methods is applied to define the other arrays `AX[k]` (with the initialization: `AX[k][i]=Agent[k][i].X`) and the arrays `AY[k]` (with the intializaition: `AY[k][i]=Agent[k][i].Y`).
- This section also contains the (compiled) arrays `iSect0[i]` and `iSect1[i]`, to reach the arrays `Agent[0][i].iSect[0]` and `Agent[0][i].iSect[1]` in the interpreted code.
- This section creates a one dimension array `FreeData[k]` to duplicate the agent members `Agent[k][i].FreeData[m]`. As previously, the reason is that EiC cannot only 1D arrays with the host application. As we duplicate a 2D array (with index `i` and `m`) by a 1D array, the dimension of `FreeData[k]` is the product of the dimensions for `i` and `m`, thus: `pData->iAMAXNb[i])*FREEPARAMNB`.
- The section highlighted with the blue bar 2 creates standard C functions for EiC.
- The section highlighted with the blue bar 3 creates the EiC arrays (i.e., the interpreter arrays) `A0X` of dimension `iAMaxNb[0]`, `A1X` of dimension `iAMaxNb[1]`, `A2X` of dimension `iAMaxNb[2]`, etc.. (via the instruction `EiC_BuildIntArray("A",i,"X",pData->iAMAXNb[i], AX[i])`, lines 51-52) . Thus: `A0X[i]=AX[0][i]=Agent[0][i].X`. This

[12] The integration in `MainAsynchronous` is very similar.

equation shows the relation between the EiC variable `A0X[i]` and the compiled variable `Agent[0][i].X` via the intermediate array `AX[0][i]`. Why this complexity? Again, because `EiC` is a C interpreter[13], not a C++ interpreter. Thus it is not possible to directly connect the 1-dimension arrays of the interpreter to members of object arrays!! The link is similar for the Y position and for all agent populations.

- The EiC arrays the (interpreter) arrays `AKFreeData[L*FREEPARAMNB+M]` `points to the array FreeData[k], thus enables to access the member variables Agent[K][L].FreeData[M]`.
- The EiC arrays `XData0` and `YData0` (lines 56 abd 58) which directly points to the compiled arrays `pData->XData[iter]` and `pData->XData[iter]` plotted by the graph functions. Remember that the GRAPH window replots in each iteration the curve defined by the arrays (`pData->XData, pData->YData`). Thus, the interpreter calculates the point of the current iteration and updates the array before plot.

Code in the file \PARSER\EiCInitialization.cpp (August 2008)

```
////////////////////////////////////////////////////////////////////////////////
THIS CODE INITIALIZES THE INTERPERETER EiC AND CREATES THE ARRAYS
//NECESSARY FOR PROCESSING THE DATA.
//NOTE THAT :
// - ARRAYS ARE CREATED ONE SINGLE TIME AS THIS SECTION OF CODE IS OUTSIDE
// THE MAIN ITERATION LOOP
// - ARRAYS DIRECTLY POINT TO ARRAYS OF THE COMPILED CODE THAT ENABLES
//        EXCHANGING DATA BETWEEN EiC AND THE HOST PROGRAM
//
////////////////////////////////////////////////////////////////////////////////
void myDisplay(char *msg);      //PROTOTYPE
short i1Nb=0; short i2Nb=0;
////////////////////////////////////////////////////////////////////////////////
//ALLOCATION OF ARRAYS TO TRANSFER AGENTS POSITION TO THE INTERPRETER. NOTE THAT
//THE ARRAYS AX[i], AY[i], AMode[i], iSect0[i], etc.. ARE ALLOCATED IN THIS
//CODE BUT NOT INITIALIZED. IN OTHER WORDS? THE SPACE IS RESERVED IN MEMORY,
//BUT THE VALUES ARE NOT DEFINED! THEY ARE DEFINED LATER IN THE CODE STORED IN
//EiCExecution.cpp
int *AX[AGENTTYPENB], *AY[AGENTTYPENB];
int *iSect0[AGENTTYPENB], *iSect1[AGENTTYPENB];
char*  AMode[AGENTTYPENB];
float* FreeData[AGENTTYPENB];
int*   iFree[AGENTTYPENB];
for (i=0;i<AGENTTYPENB;i++) { //ALL OBJECTS ARE DELETED IN EiCEnd.cpp
        AX[i]= new int[pData->iAMAXNb[i]];
        AY[i]= new int[pData->iAMAXNb[i]];
        AMode[i]=new char[pData->iAMAXNb[i]];
        iSect0[i]=new int[pData->iAMAXNb[i]];   //FOR ARRAY Agent[i][j].iSect[0]
        iSect1[i]=new int[pData->iAMAXNb[i]];   //FOR ARRAY Agent[i][j].iSect[1]
        //ARRAY TO STORE THE FREE PARAMETERS OF THE AGENTS OF TYPE i. NOTE THAT WE
        //WE STORE THE 2D ARRAY BY A 1D ARRAY BY MULTIPLYING THE DIMENSIONS
        FreeData[i]= new float[(pData->iAMAXNb[i])*FREEPARAMNB];
        iFree[i]   = new int  [(pData->iAMAXNb[i])*FREEPARAMNB];
}
////////////////////////////////////////////////////////////////////////////////
XEiC_init_EiC();                                  //INITIATE EiC
XEiC_setMessageDisplay(myDisplay);//SET THE FUNCTION USED TO DISPLAY EiC'S ERRORS
//REDUCED math.h HEADER FOR EiC
XEiC_parseString("      double acos(double a);                          ");
```

[13] To our knowledge, there is no C++ interpreter

```
XEiC_parseString("      double asin(double a);                          ");
XEiC_parseString("      double atan(double a);                          ");
XEiC_parseString("      double atan2(double a, double b);               ");
XEiC_parseString("      double cos(double a);                           ");
XEiC_parseString("      double sin(double a);                           ");
XEiC_parseString("      double tan(double a);                           ");
XEiC_parseString("      double cosh(double a);                          ");
XEiC_parseString("      double sinh(double a);                          ");
XEiC_parseString("      double tanh(double a);                          ");
XEiC_parseString("      double exp(double a);                           ");
XEiC_parseString("      double frexp(double a, int * b);                ");
XEiC_parseString("      double ldexp(double a, int b);                  ");
XEiC_parseString("      double log(double a);                           ");
XEiC_parseString("      double log10(double a);                         ");
XEiC_parseString("      double modf(double a, double *b);               ");
XEiC_parseString("      double pow(double a, double b);                 ");
XEiC_parseString("      double sqrt(double a);                          ");
XEiC_parseString("      double ceil(double a);                          ");
XEiC_parseString("      double fabs(double a);                          ")
XEiC_parseString("      double floor(double a);                         ");
XEiC_parseString("      double fmod(double a, double b);                ");
////////////////////////////////////////////////////////////////////////////
EiC_Define("AGENTTYPENB",AGENTTYPENB);
XEiC_parseString("int i,j;");
EiC_BuildShortArray("ANb",AGENTTYPENB,pData->iAMAXNb);
EiC_BuildShort("i2Nb", &i2Nb);
EiC_BuildFloat("RefreshPeriod",&pData->ScreenShotPeriod);
EiC_BuildFloat("XMin",&pData->XMinChart);
EiC_BuildFloat("XMax",&pData->XMaxChart);
EiC_BuildInt("iter", &iter);
for (i=0;i<AGENTTYPENB;i++) {
     //INTERPRETER ARRAY AKX[j] SUCH THAT AKX[j]=Agent[K][j].X
     EiC_BuildIntArray("A",i,"X",pData->iAMAXNb[i],AX[i]);
     //INTERPRETER ARRAY AKY[j] SUCH THAT AKY[j]=Agent[K][j].Y
     EiC_BuildIntArray("A",i,"Y",pData->iAMAXNb[i],AY[i]);
     //INTERPRETER ARRAY AKMode[j] SUCH THAT AKMode[j]=Agent[K][j].Mode
     EiC_BuildCharArray("A",i,"Mode",pData->iAMAXNb[i],AMode[i]);
     //INTERPRETER ARRAY AKSect0 SUCH THAT AKSect0[j]=Agent[K][j].iSect[0]
     EiC_BuildIntArray("A",i,"Sect0",pData->iAMAXNb[i],iSect0[i]);
     //INTERPRETER ARRAY AKSect1 SUCH THAT AKSect1[j]=Agent[K][j].iSect[1]
     EiC_BuildIntArray("A",i,"Sect1",pData->iAMAXNb[i],iSect1[i]);
     //THIS INTERPRETER ARRAY AKFreeData WILL BE USED TO STORE THE FreeData OF EACH
     //AGENT SUCH THAT : AKFreeData[L*FREEPARAMNB+M]=Agent[K][L].FreeData[M]
     EiC_BuildFloatArray("A",i,"FreeData",(pData->iAMAXNb[i])*FREEPARAMNB,FreeData[i]);
     //THIS INTERPRETER ARRAY AKIFree WILL BE USED TO STORE THE iFree OF EACH
     //AGENT SUCH THAT : AKIFree[L*FREEPARAMNB+M]=Agent[K][L].iFree[M]
     EiC_BuildIntArray("A",i,"IFree",(pData->iAMAXNb[i])*FREEPARAMNB,iFree[i]);
}
////////////////////////////////////////////////////////////////////////////
//INTERPRETER ARRAY SUCH THAT XData0[i]=pData->XData[i] FOR GRAPH DISPLAY
EiC_BuildFloatArray("XData",0,"",pData->iChartPtNb,pData->XData);
//INTERPRETER ARRAY SUCH THAT YData0[i]=pData->YData[i] FOR GRAPH DISPLAY
EiC_BuildFloatArray("YData",0,"",pData->iChartPtNb,pData->YData);
EiC_BuildInt("iChartPtNb", &pData->iChartPtNb);
////////////////////////////////////////////////////////////////////////////
//DEFAULT CODE IN THE EDIT CONTROL OF CParamPage4 IF NO CODE DEFINED
if (pData->EiC_CODE=="") { //DEFAULT MINIMUM CODE
        pData->EiC_CODE=               "int i,j;";
        pData->EiC_CODE=pData->EiC_CODE+"i2Nb=0;";
        pData->EiC_CODE=pData->EiC_CODE+"for (i=0;i<ANb[1];i++) {";
        pData->EiC_CODE=pData->EiC_CODE+"    if (A1Mode[i]=='A') { i2Nb=i2Nb+1; }";
        pData->EiC_CODE=pData->EiC_CODE+"}";
        pData->EiC_CODE=pData->EiC_CODE+"if (iter<iChartPtNb) {";
        pData->EiC_CODE=pData->EiC_CODE+"    XData0[iter]= iter;";
```

```
        pData->EiC_CODE=pData->EiC_CODE+"    YData0[iter]= i2Nb;";
        pData->EiC_CODE=pData->EiC_CODE+"}";
        pData->EiC_CODE=pData->EiC_CODE+"else {";
        pData->EiC_CODE=pData->EiC_CODE+"    XData0[iChartPtNb-1]= iter;";
        pData->EiC_CODE=pData->EiC_CODE+"    YData0[iChartPtNb-1]= i2Nb;";
        pData->EiC_CODE=pData->EiC_CODE+"}";
}
```

Script 12: Code in \PARSER\EICInitialization.cpp

This code shows the difficulties to exchange data between the compiled code and the interpreter. The following interpreter variables are (so far) defined to access compiled code variables:

Variable	EiC variable
AGENT VARIABLES	
X position of agent of Rank L and Type=K	`AKX[L]` `0<=K<6, 0<L<iANb[K]`
Y position of agent of Rank L and Type=K	`AKY[L]` `0<=K<6, 0<L<iANb[K]`
Number of agents of Type K	`iANb[K]  0<=K<6`
Activity flag of agents of Type K	`AKMode[L]` `0<=K<6, 0<L<iANb[K]`
Move angle of agent of Rank L, Type K, in the current iteration	`AKSect0[L]` `0<=K<6, 0<L<iANb[K]`
Move angle of agent of Rank L, Type K, in the previous iteration	`AKSect1[L]` `0<=K<6, 0<L<iANb[K]`

float FreeData`[FREEPARAMNB]`: Array of the agent of index j and Atype K. This array is mapped to the interface.	`AKFreeData[L*FREEPARAMNB+m]`
	`0<=K<6; 0<L<iANb[K]`
	`0≤m<FREEPARAMNB`

int iFree`[FREEPARAMNB]`: Array of free integer array	`AKIFree[L*FREEPARAMNB+m]`
	`0<=K<6, 0<L<iANb[K]`
	`0≤m<FREEPARAMNB`

CHART VARIABLES	
Index of the current Iteration	`Iter`
Index of the current screen shot IterationArray of X coordinates plotted in the Graph window	`IterXData0[i]`
Array of X coordinates plotted in the Graph window returned to the charting toolArray of Y coordinates plotted in the Graph window	`XData0[i]YData0[i]`
Array of Y coordinates returned to the charting tool plotted in the Graph windowNumber of points in the a curve	`YData0[i]iChartPtNb`
Number of points in the a curve	`iChartPtNb`
`Minimum of X Axis`	`XMin`
`Maximum of X Axis`	`XMax`

Table 1: Correspondence of compiled and interpreted variables

The definitions in Table 1 ought to be extended to all the member variables of the AGENT class.

A3.2 #include "EiCExecution.cpp" (August 2008)

Note in particularly the grayed section, which duplicates the members variables `pData->Agent[ii][jj].FreeData[kk]` in a One dimension array over `jj` and `kk`.

```
////////////////////////////////////////////////////////////////////////////
//
//      THIS CODE IS INCLUDED IN THE FUNCTION void MainTest(COREDATA* pData)
//      IN THE FILE MAIN.CPP
//
////////////////////////////////////////////////////////////////////////////
//UPDATE THE VALUES STORED IN THE EiC ARRAYS AND RUN THE INTERPRETER
for (int ii=0;ii<AGENTTYPENB;ii++) for (int jj=0;jj<pData->iAMAXNb[ii];jj++)
{
        AX[ii][jj]= pData->Agent[ii][jj].X;     //X POSITION OF THE AGENTS
        AY[ii][jj]= pData->Agent[ii][jj].Y;     //Y POSITION OF THE AGENTS
        AMode[ii][jj]=pData->Agent[ii][jj].AgentMode;   //Mode OF THE AGENTS
        iSect0[ii][jj]=pData->Agent[ii][jj].iSect[0];   //iSect[0] OF AGENTS
        iSect1[ii][jj]=pData->Agent[ii][jj].iSect[1];   //iSect[1] OF AGENTS
        for (int kk=0;kk<FREEPARAMNB;kk++) {
           FreeData[ii][jj*FREEPARAMNB+kk]= pData->Agent[ii][jj].FreeData[kk];
           iFree[ii][jj*FREEPARAMNB+kk]   = pData->Agent[ii][jj].iFree[kk];
        }
}
//IF "infinite mode", SHIFT ARRAY TO SHIFT CHART DISPLAY
if (iter>=pData->iChartPtNb)
for (int kk=0;kk<(pData->iChartPtNb-1);kk++){
        //SHIFT THE POINTS THAT ARE DISPLAYED BY THE GRAPHER
        pData->XData[kk]=pData->XData[kk+1];
        pData->YData[kk]=pData->YData[kk+1];
}
////////////////////////////////////////////////////////////////////////////////
//PROTECT THE VARIABLES USED IN EiC_parseString AGAIN ANY CONCURENT READ OR WRITE
//OPERATION POSSIBLY SIMULTANEOUSLY ATTEMPTED BY ANOTHER THREAD, IN PARTICULAR BY A
//USER-TRIGGERED INTERFACE UPDATE. REMEMBER THAT EiCparString WRITES THE ARRAY XData0[i]
//WHICH IS READ BY THREAD1 IN THE CHART MODE
WaitForSingleObject(pApp->m_hSafe1,INFINITE);
////////////////////////////////////////////////////////////////////////////////
//RUN EiC TO INTERPRETE THE STRING THAT CALCULATES DE DATA FOR THE GRAPHER
XEiC_parseString(pData->EiC_CODE.GetBuffer(pData->EiC_CODE.GetLength()));
////////////////////////////////////////////////////////////////////////////
SetEvent(pApp->m_hSafe1);  //FREE THE ACCESS TO THE PROTECTED VARIABLES BY THE CODE
                           //BLOCKED BY WaitForSingleObjet(m_hSafe1)
////////////////////////////////////////////////////////////////////////////////
```

Script 13: Code of EicExecution.cpp

Note that this code is in the iteration loop of `MainTest` so that the interpreter calculates data for GRAPH in each iteration.

A3.3 #include "EiCEnd.cpp"

Code in the file \PARSER\EiCEnd.cpp

```
////////////////////////////////////////////////////////////////////////////
//
// THIS CODE IS INCLUDED IN THE FUNCTION void MainTest(COREDATA* pData)
// IN THE FILE MAIN.CPP
//
////////////////////////////////////////////////////////////////////////////
//THIS CODE DELETES THE ARRAY DYNAMICALLY CREATED IN EiCInitialization.cpp
```

```
////////////////////////////////////////////////////////////////////////////
//DELETE OBJECTS CREATED TO INITIALIZE EiC
for (i=0;i<AGENTTYPENB;i++)
{
      delete [] AX[i];
      delete [] AY[i];
      delete [] AMode[i];
      delete [] iSect0[i];
      delete [] iSect1[i];
      delete [] FreeData[i];
      delete [] iFree[i];
}
////////////////////////////////////////////////////////////////////////////
```

Script 14: Code of EicEnd.cpp

WARNING: One persistent issue when writing new plot functions with EiC is that the application sometime aborts when errors are detected by the interpreter. To partly circumvent this issue, the code of the edition window is always saved prior to running the threat which embeds the interpreter and which may cause the execution abortion.

A.4 Where are the functions for interpreting ?

The functions invoking the interpreter are in the blocks

```
#include "EiCInitialization.cpp"
#include "EiCExecution.cpp"
#include "EiCEnd.cpp"
```

which are located in the functions

- `MainSynchronous(COREDATA* pData) in MainSynchronous.cpp`
- `MainAsynchronous(COREDATA* pData) in MainAsynchronous.cpp`

These files includes the header: `#include "..\PARSER\EiCFunctions.h"`
The code is below:

//EiCFunctions.h

```
////////////////////////////////////////////////////////////////////////////
//      FUNCTION PROTOTYPES TO LINK EiC TO C++ CODE
////////////////////////////////////////////////////////////////////////////

//ENTRY FUNCTION DEFINED IN THE DLL EIC_DLL.dll

_declspec(dllexport) void XEiC_init_EiC(void);
_declspec(dllexport) void XEiC_setMessageDisplay(void (*)(char *));
_declspec(dllexport) void XEiC_parseString(char* MyStr);
//_declspec(dllexport) void XEiC_parseString(CString MyStr);

_declspec(dllexport) CString Build(char* achName1, int i,char* achName2);
_declspec(dllexport) void EiC_Define(char* Str1, int iVal);
_declspec(dllexport) void EiC_BuildDoubleArray(char* ArrayName1,int i,char*
ArrayName2, int iDim, double* pSource);
_declspec(dllexport) void EiC_BuildFloatArray(char* ArrayName1,int i,char*
ArrayName2, int iDim, float* pSource);
_declspec(dllexport) void EiC_BuildIntArray(char* ArrayName1,int i,char* ArrayName2,
int iDim, int* pSource);
```

```
_declspec(dllexport) void EiC_BuildCharArray(char* ArrayName1,int i,char* ArrayName2,
int iDim, char* pSource);
_declspec(dllexport) void EiC_BuildIntArray(char* ArrayName, int iDim, int* pSource);
_declspec(dllexport) void EiC_BuildShortArray(char* ArrayName, short iDim, short*
pSource);
_declspec(dllexport) void EiC_BuildInt(char* iName, int* iSourceName);
_declspec(dllexport) void EiC_BuildShort(char* iName, short* iSourceName);
_declspec(dllexport) void EiC_BuildFloat(char* iName, float* iSourceName);
//////////////////////////////////////////////////////////////////////////
```

The header code shows that all functions to interpret the code are in a DLL entitled EIC_DLL! This code exportation became necessary when upgrading the compiler from VisualC++6 to VisualC++8 because we face complex linkage problems. The DLL Code is in the project: 080730EIC_DLL_VC6. Another project is integrated in 080730TEST_EICDLL_VC6.

CRITICAL WARNING: The DLL DLL_EIC.dll (generated by the project EIC_DLL) MUST BE COMPILED with the compiler VisualC++6 even the CORE and the application DLLs (in the directories DLL and TUTORIAL) are upgraded and compiled with VisualC++8

B Syntax-colored editor

The syntax-colored editor (SCE) is an extension of the `CrichEditCtrl` class that includes a parser to color the syntax. The code is in `ParamPage4.cpp` and `ParamPage4.h`. The coloring tool is in the `class CsyntaxColorizer` in the files `syntaxColorizer.cpp` and `syntaxColorizer.h`.

The SCE enables auto-indentation when a new line is inserted in the code.

C DLL approach

As stressed in the introduction, the second solution to calculate user-defined agent properties at run time consists in writing the corresponding function a DLL.

The selection between the two methods (i.e., Interpreter versus DLL approach) is achieved by checking the box entitled "Function in DLL" in the top right corner of the property page shown in Fig. 21 page 73.

The function code must be exclusively in the DLL of the first agent. This property is mandatory. We show below an example of code in the DLL.

```
__declspec(dllexport) void GraphFunc(AGENT* Agent[AGENTTYPENB],
                                     short iAgentNb[AGENTTYPENB],
                                     CELL* Cell, int XDim, int YDim,
                                     float* XData,float* YData, int iGraphPtNb,
                                     int iter)
//////////////////////////////////////////////////////////////////////////
//      HISTORY: FIRST IMPLEMENTATION jFeb 2004, JHC
//////////////////////////////////////////////////////////////////////////
```

```
{
    int i=0;
////////////////////////////////////////////////////////////////////////////
        int iInbuffer=0;
        if (iter<iGraphPtNb) {
            for (i=0;i<iAgentNb[0];i++) {
                if (Agent[0][i].AgentMode =='A') {
                    iInbuffer=iInbuffer+Agent[0][i].pNode->InBuffer[0].m_iBufSize;
                }
            }
            XData[iter]=(float) iter;
            YData[iter]=(float) ((10.0*iInbuffer)/iAgentNb[0]);
        }
         else { //IMPORTANT CODE TO AVOIDE ABORTION IF iter>=iGraphPtNb
            XData[iGraphPtNb-1]= (float) iter;
            YData[iGraphPtNb-1]= (float) 0;
        }
////////////////////////////////////////////////////////////////////////////
}
```

Chapter 5

Agent property visualization: CHART

The CHART module displays the data calculated with the INTERPRETER described in the previous chapter.

The charting module is derived from the code initially written by Massimo Colurcio. It is available from the following web page http://www.codeguru.com/article.php/c2241 of the CodeGuru site. We added many extensions to the original version, which provided no runtime interactivity to customize the different chart elements as the colors (for lines, markers, labels, background…), the styles (for lines, markers…), the sizes (lines, markers, labels…). A typical chart is displayed in Fig. 23.

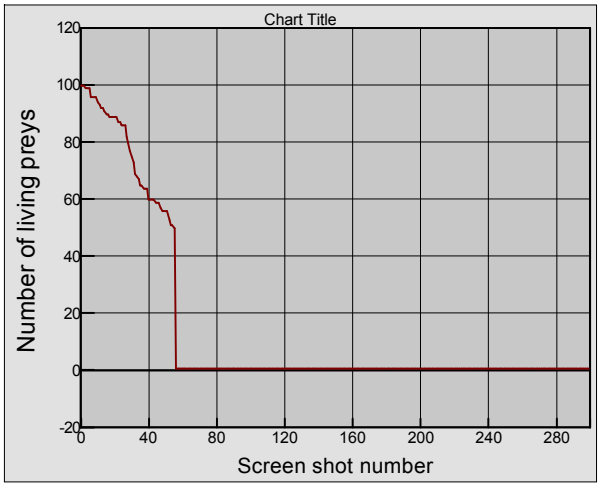


Fig. 23: Example of chart generated by the module CHART. This figure shows the decay of the number of preys for different predator policies.

The current version makes the chart fully customizable at runtime through the integration of 3 property pages. It includes the following features:

- Extension of the basic charting capabilities from the original classes CXChart, CXDataSet written by Massimo Colurcio. In particular, the chart becomes a a separate and resizable window.
- Customization at runtime, using a property sheet (based on the classes `CChartPropFrame`, `CChartPropSheet`, `CChartPropPage1`, `CChartPropPage2`, `CChartPropPage3`, `CChartPropPage4`) and color selection using the classes `CColorButton` and `CColourPopUp`.
- Registration of the chart parameters in the scenario file (with the extension MAS) using the XML format.
- Registration of the chart image in the paste buffer. The chart is saved in the WMF format.

A Chart area decomposition

A chart is a window derived from the generic class `CWnd`. The declaration is: `class CXChart : public CWnd` (see the header declaration in paragraph DD.1 page 93). This class includes several `CRect` declarations

```
CRect     m_rectUsable;          // usable area
CRect     m_rectData;            // data area
CRect     m_rectGraph;           // graph area
CRect     m_rectXAxis;           // x axis area
CRect     m_rectYAxis;           // y axis area
CRect     m_rectTitle;           // main title area
CRect     m_rectArea;            // entire control area
```

to decompose the chart shown in Fig. 23 in a series of imbricate rectangles, containing the different elements (the chart title, the axis, the axis labels…). We distinguish:

- The topmost rectangle is `m_rectArea`, which is nothing but the client rectangle of the class `CXChart` of the chart code. The WIN32 function `GetClientRect(m_rectArea)` retreives the coordinates of this window `m_rectArea.top=0` and `m_rectArea.left=0` **so that all coordinates in the description of this module are relative to the top left corner of the client area**. `m_rectArea` includes all other rectangles.
- The usable rectangle `m_rectUsable` (represented in the next figure) is defined to eliminate user-defined margins (see the code below).

```
m_rectUsable.top    = m_rectArea.top    + m_rectArea.Height()/HMX_AREA_MARGINS;
m_rectUsable.bottom = m_rectArea.bottom - m_rectArea.Height()/HMX_AREA_MARGINS;
m_rectUsable.left   = m_rectArea.left   + m_rectArea.Width() /HMX_AREA_MARGINS;
m_rectUsable.right  = m_rectArea.right  - m_rectArea.Width() /HMX_AREA_MARGINS;
```

`HMX_AREA_MARGINS` is typically 80 so that the margin represents 5% of the height and 5% of the width of m_rectArea.

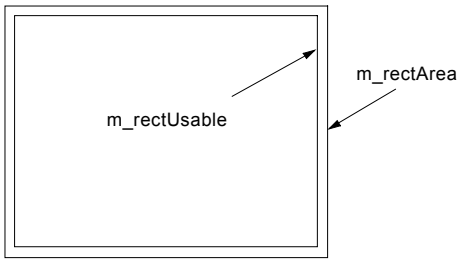


Fig. 24: Representation of the rectangles `m_rectArea` and `m_rectUsable`

- The usable rectangle, `m_rectUsable` is decomposed in two rectangles, the Title rectangle and the Graph rectangle respectively entitled `m_rectTitle` and `m_rectGraph` (see the code below).

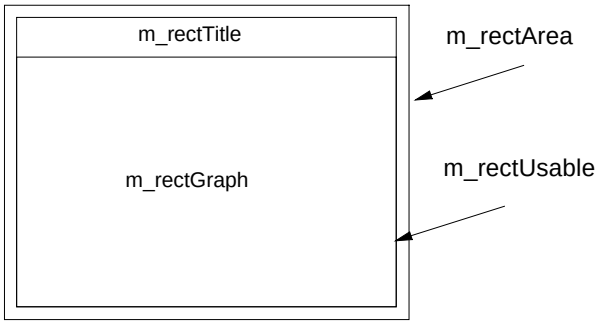


Fig. 25

```
m_rectTitle.top    = m_rectUsable.top;
m_rectTitle.left   = m_rectUsable.left;
m_rectTitle.bottom = m_rectUsable.bottom/HMX_AREA_TITLE;
m_rectTitle.right  = m_rectUsable.right;
m_rectGraph.top    = m_rectTitle.bottom;
m_rectGraph.left   = m_rectUsable.left;
m_rectGraph.bottom = m_rectUsable.bottom;
m_rectGraph.right  = m_rectUsable.right;
```

- m_rectGraph is decomposed as represented in Fig. 26 to define the rectangles `m_rectYAxis`, `m_rectXAxis`, and `m_rectData`.

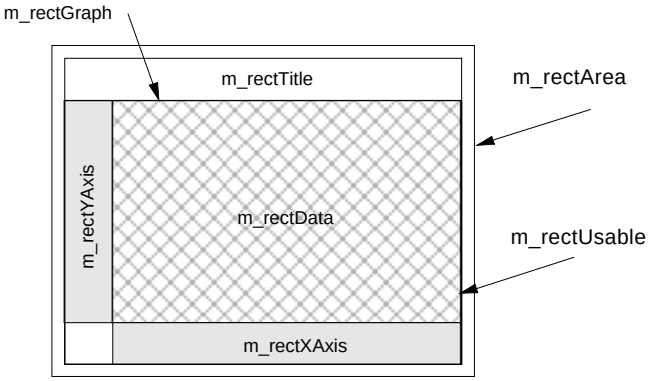


Fig. 26

```
m_rectYAxis.top    = m_rectGraph.top;
m_rectYAxis.left   = m_rectGraph.left;
m_rectYAxis.bottom = m_rectGraph.top  + m_rectGraph.Height()*(100-HMX_AREA_XAXIS)/100;
m_rectYAxis.right  = m_rectGraph.left + m_rectGraph.Width()*(HMX_AREA_YAXIS)/100;

m_rectXAxis.top    = m_rectGraph.top  + m_rectGraph.Height()*(100-HMX_AREA_XAXIS)/100;
m_rectXAxis.left   = m_rectGraph.left + m_rectGraph.Width()*(HMX_AREA_YAXIS)/100;
m_rectXAxis.bottom = m_rectGraph.bottom;
m_rectXAxis.right  = m_rectGraph.right;

m_rectData.top     = m_rectGraph.top;
m_rectData.bottom  = m_rectXAxis.top;
m_rectData.left    = m_rectYAxis.right;
m_rectData.right   = m_rectGraph.right;
```

Fig. 27 shows the placement of the different rectangles that we just described in a real graph.

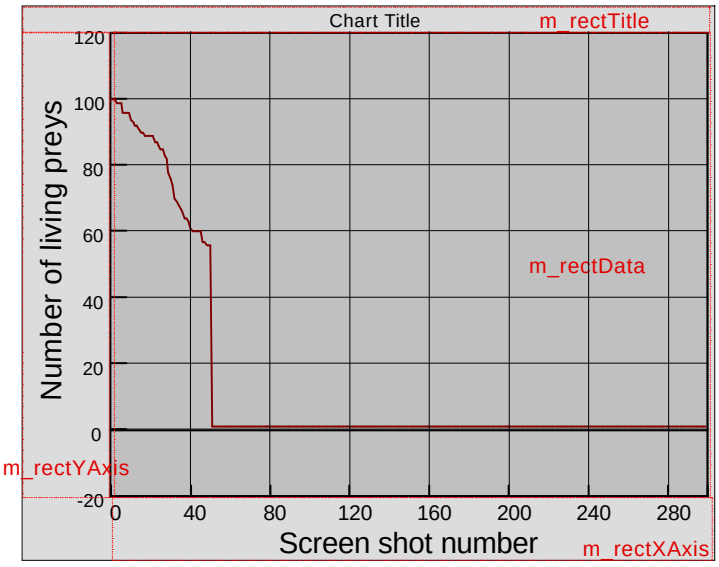


Fig. 27: Placement of rectangles in a real chart

B Charting modes

B.1 Type-1 chart: time kinetics

In general, a chart includes several data lines, as represented in Fig. 32. Recall that the chart is periodically updated when the screen is painted. With type-1 charts, one single point of a single data line is recalculated between two successive screen shots (see Fig. 28). In other words, the painting operation changes one data point in the screen, and to some extend, it is only necessary to redraw the data line close to the recalculated point.

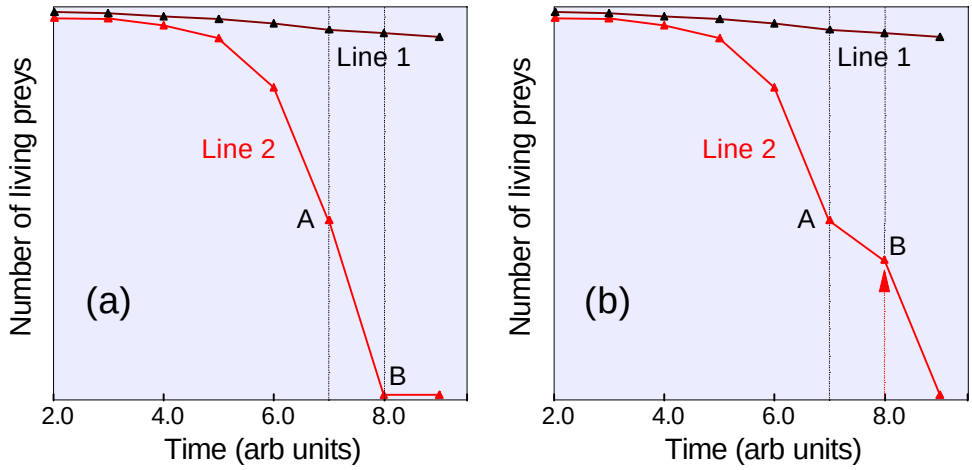


Fig. 28: Examples of two successive drawings of a chart in the mode I. In this example, data displayed by line number 2 are being calculated and the line is under construction. Point B in still not calculated in figure (a). Contrarily, It has been calculated in figure (b) and line is updated accordingling. One single point (B here) is drawn between two successive plots.

This mode is appropriate to plotting the time kinetics of any parameter during the simulation run. However, as the whole data line is displayed before the end of the simulation, some points corresponding to future data that are temporarily unknown. Thus the simulation begins by initializing all YData0[i] values to 0, i.e, `YData0[i]=0` for all i.

In this charting mode, the number of data points is automatically setup to `nCount=ThreadData.iScreenShotNb`, i.e., the number of screen shots adjusted in `ParamPage1`. Thus, `XData0[i]=i*ThreadData.iScreenShotPeriod`. The sole point of coordinates (`XData0[iter],XData0[iter]`) is updated, where iter is the screen shot iteration index.

B.2 Type-2 chart

With type-2 charts, all data points of the curve under consideration are recalculated between two successive plots. Thus, the charting tools must completely redraw the data line. In other words, the plotted curve represents any function F(S,t) calculated at points S_i equally spaced between S_{Min} and S_{Max}. The program plots $F(S,t_0)$ at screen shot 0, $F(S,t_0+\Delta T)$ at screen shot 1, $F(S,t_0+2\Delta T)$ at screen shot 2, and so on.

Let us consider an example for clarity. The interpreter code below calculates the number of agents N(x) (i.e., the agent distribution in the terrain) versus their position with 0≤x<XDim.

```
1       for (i=0;i<iChartPtNb;i++) YData0[i]=0;
2       for (i=0;i<ANb[0];i++) {
3                       if (A0Mode[i]=='A') {
4                               YData0[A0X[i]]=YData0[A0X[i]]+1;
5                       }
             }
```

`YData0[i]` is the number of agents in the terrain at the abscissa `Agent.X=i`, with possibly different Y coordinates. The code first resets all `YData0[i]` to 0 (line 1). Then, it scans all agents `iAtype=0` (`line 2`). If the agent is active, it increments the occupation `YData0[i]` at the agent abscissa, i.e., it increments `A0X[i]]` (line 4). The important point for the charting tool is that this code recalculates all points of the curve and therefore shows the time evolution of the agent distribution.

In Type-2 charts, the chart point number `nCount` is arbitrarily defined in ParamPage4 (see Fig. 29), as well as the minimum and maximum values X_{Min} and X_{Max} of `XData0[i]`. However, remember that the restriction persists to consider equally spaced points between X_{Min} and X_{max}.

C Function calls in the charting process

The function calls are represented by the script below.

```
CParamSheet::OnRunSession()
    CParamSheet::SaveAndRebuildAll()
         CParamSheet::TransferPage4ParametersToThreadData()
         CAGNTView::StartThread
              MainTestAsynchronous(COREDATA*)
             GraphicUpdate(COREDATA*,int)//SENDS MESSAGE TO OnUpdateDisplay

                   CAGNTView::OnUpdateDisplay(WPARAM,LPARAM)
                        CAGNTView::DrawChart(int)
                             CXChart::Invalidate()
                                  CXChart::CalcDatas()
                                  CXChart::PaintBkGnd(CDC)
                                  CXChart::PaintDataArea(CDC)
                                  CXChart::DrawTitle(CDC)
                                  CXChart::DrawVertLine(CDC)
                                  CXChart::DrawTicksX(CDC)
                                  CXChart::DrawHorzLine(CDC)
                                  CXChart::DrawTicksY(CDC)
                                  CXChart::DrawFrame(CDC)
                                  CXChart::DrawBaseline(CDC)
                                  CXChart::DrawAxes(CDC)
                                  CXChart::DrawYScale(CDC,BOOL);
                                  CXChart::DrawXScale(CDC,BOOL)
                                  CXChart::DrawDatasets(CDC)
```

Script 15

Let us describe this script in details. The **CORE** proceeds as follows when a simulation is launched:

1. The control is transferred to the function `CParamSheet::OnRunSession` which calls `CParamSheet::SaveAndRebuildAll()`. This function, first calls `TransferPage4ParametersToThreadData()`, which saves the values of parameters in the edit boxes of ParamPage4 represented below

- The value of the edit box "Nb of Graph Points" is saved to `ThreadData.iChartPtNb`.
- The value of the edit box "Graph mode" is saved to `ThreadData.iChartMode`. There are 2 chart modes, in accordance with the description of the previous paragraph
- The value of the edit box "XMin" is saved to `ThreadData.XMinChart`.
- The value of the edit box "XMax" is saved to `ThreadData.iXMaxChart`.

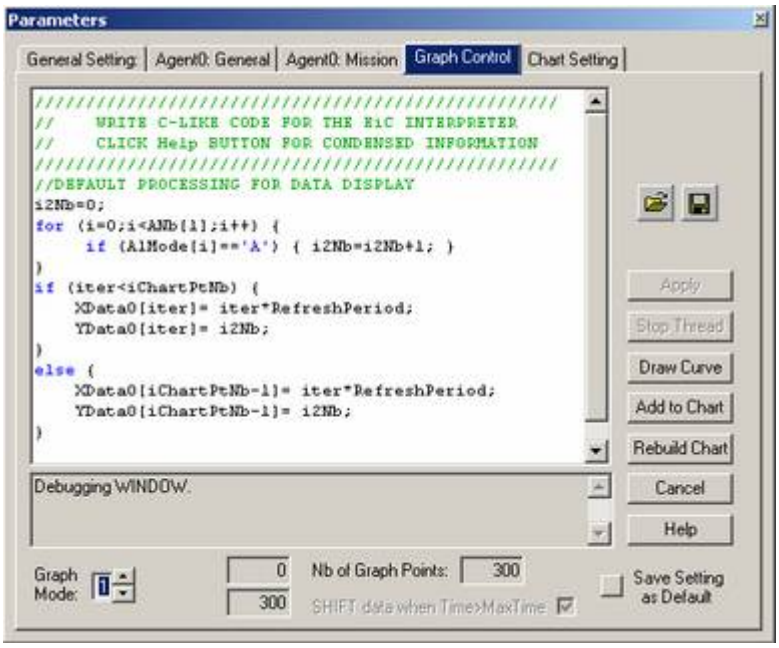


Fig. 29

2. `CParamSheet::SaveAndRebuildAll()` reallocates the arrays `XData` and `YData`, which are periodically calculated by the interpreter and passed to `CXChart` during the simulation run. In the chart mode I, the dimension of these arrays is automatically set to `ThreadData.iScreenShotNb` in accordance with the description of Type-1 charts. The relevant code in is below:

```
//VERY IMPORTANT LINE: AUTOMATIC RESET OF THE NB OF POINTS TO THE NUMBER OF
//SCREEN SHOTS IN THE CHART MODE iChartMode=1
if (pView->ThreadData.iChartMode==1)
             pView->ThreadData.iChartPtNb=pView->ThreadData.iScreenShotNb;
delete [] pView->ThreadData.XData; delete [] pView->ThreadData.YData;
pView->ThreadData.XData = new float[pView->ThreadData.iChartPtNb];
pView->ThreadData.YData = new float[pView->ThreadData.iChartPtNb];
//TEMPORARY INITIALIZATION OF XData AND YData. THESE ARRAYS ARE UPDATED BY THE
//INTERPRETER IN THE SIMULATION LOOP
for (i=0;i<pView->ThreadData.iChartPtNb;i++) {
    pView->ThreadData.XData[i]=
    (float) i*pView->ThreadData.ScreenShotPeriod;//DEFAULT X, TEMPORARY
            pView->ThreadData.YData[i]=1;        //DEFAULT Y, TEMPORARY
}
```

3. `CParamSheet::OnRunSession` transfers the control to `CAGNTView::StartThread`, which starts the simulation thread and executes `MainAsynchronous` or `MainSynchronous`.

4. `MainTestAsynchronous` executes the include instruction

```
#include "..\PARSER\EiCExecution.cpp"
```

This code computes (following the user-written script) the array `XData[i]` and `YData[i]`. For a Type-1 chart, you only need to calculate the point `XData[iter]` and `YData[iter]`, where `iter` is the index of the current screen shot.

Example of script for Type-1 chart: In the EiC code, XData and YData are respectively replaced by XData0, and YData0. This code counts the number of living agents of type1.

```
i2Nb=0;
for (i=0;i<ANb[1];i++) {
          if (A1Mode[i]=='A') { i2Nb=i2Nb+1; }
}
XData0[iter]= iter*RefreshPeriod;
YData0[iter]= i2Nb;
```

Example of script for Type-2 chart: All data points are recalculated.

```
//DENSITY PROFILE (Distribution0.EIC)
for (i=0;i<iChartPtNb;i++) {
     YData0[i]=0;
     XData0[i]=XMin+i*(XMax-XMin)/iChartPtNb;
}
for (i=0;i<ANb[0];i++) {
     if (A0Mode[i]=='A') {
         YData0[A0X[i]]=YData0[A0X[i]]+1;
     }
}
```

5. The function `MainTestAsynchronous()` calls `GraphicUpdate()`, which sends the message `WM_UPDATE_DISPLAY (through the instruction SendMessage(pData->m_ViewhWnd,WM_UPDATE_DISPLAY,iter,0)) to CAGNTView::OnUpdateDisplay.`

6. `CAGNTView::OnUpdateDisplay` calls `CAGNTView::DrawChart(int)`, the code of which is duplicated below. `CAGNTView::DrawChart` first tests whether the chart window exists (line ?). If it does not, it creates the chart window with the instruction `m_chart.CreateChart()` (line??). The chart is never destroyed in the code. It is hidden when it is not used. Thus, the section of `DrawChart,` which creates the chart, is executed one single time during a session. Note that the function `DrawChart` does not directly draw the chart! It calls `m_chart.Invalidate(TRUE)` or the SDK function `InvalidateRect` to execute the member function `CXChart::OnPaint()`.

```
void CAGNTView::DrawChart(int iter)
////////////////////////////////////////////////////////////////////////////////
// HISTORY: Version 1.0; SUMMER 2002, AUTHOR JHC
//                    2.0; AUGUST 2003, JHC, CODE MADE SIMPLER
//                  3.0: AUGUST 2003; COMPLETELY REWRITTEN TO USE THE CXChart CLASS
//                         INSTEAD OF CGraph. JHC
////////////////////////////////////////////////////////////////////////////////
{
    int i=0,j=0;
    CClientDC dc(this);
////////////////////////////////////////////////////////////////////////////////
    CString sBuffer;
    iDisplayMode=1
////////////////////////////////////////////////////////////////////////////////
//NO CHART WINDOW AT THE MOMENT! THIS SECTION IS EXECUTED ONE SINGLE TIME!
    if (!::IsWindow(m_chart.m_hWnd)) {
       m_chart.CreateChart(this->m_hWnd);
       for (int i = 0; i < ThreadData.iChartPtNb; i++)      {
           m_chart.SetData( 0, 1.0*ThreadData.YData[i]);
           sBuffer.Format("%5.1f", ThreadData.XData[i]);//5 CHARS, WITH ONE DIGIT
```

```
            m_chart.SetXScaleLabel( i, sBuffer );
        }
        m_chart.SetDatasetMarker(0,HMX_DATASET_MARKER_TRI );//PARAMETER 1: CHART INDEX
        m_chart.SetDatasetPenColor(0,m_chart.BASECOLORTABLE[0]);
        m_chart.SetDatasetPenSize(0,3 );
        m_chart.SetYTicks( 10 );            //NB OF TICKS IN THE Y AXE!
        m_chart.SetRoundY( 20 );
        m_chart.SetTitle("Chart Title");
        //NB OF POINTS BETWEEN 2 TICKS OF THE X AXE
        m_chart.SetXLabelStep(XStep(ThreadData.iChartPtNb));
        m_chart.SetYText("Prey number");
        m_chart.SetXText("Screen shot number");
        iDrawnCurveNb=1;               //VERY IMPORTANT
        m_chart.m_bFullPaint=true;
        m_chart.Invalidate(TRUE);      //THUS THE PROGRAM EXECUTES m_chart.OnPaint()
        return;
    }
////////////////////////////////////////////////////////////////////////////////
    //REGULAR CODE WHEN THE CHART WINDOW EXISTS
    //PART 1: UPDATE DATA
    m_chart.SetDatasetPenSize(iNextCurveIndex,3);
    m_chart.SetDatasetMarker( iNextCurveIndex, HMX_DATASET_MARKER_TRI );
    if (iNextCurveIndex<iDrawnCurveNb) {      //YOU REDRAW AN EXISTING LINE
        for (int i = 0; i < ThreadData.iChartPtNb; i++)      {
            m_chart.ResetData( iNextCurveIndex, i, 1.0*ThreadData.YData[i]);
            //      sBuffer.Format("%d", i );
            //m_chart.SetXScaleLabel( i, sBuffer );
        }
    }
    else if (iNextCurveIndex==iDrawnCurveNb) {  //YOU ADD A NEW LINE. THIS SECTION IS
        iDrawnCurveNb=iDrawnCurveNb+1;          //EXECUTED ONE SINGLE TIME!
         m_chart.SetDatasetPenSize( iNextCurveIndex, 3 );
         for (int i = 0; i < ThreadData.iChartPtNb; i++)      {
             m_chart.SetData( iNextCurveIndex, 1.0*ThreadData.YData[i]);
             //sBuffer.Format("%d", i );
             //m_chart.SetXScaleLabel( i, sBuffer );
         }
    }
    ////////////////////////////////////////////////////////////////////////////
    //PART 2: UPDATE DISPLAY
    //THE GOAL OF THESE LINES IS TO DETERMINE A REDUCED RECTANGLE AROUND THE CURRENT
    //NEW POINT TO INVALIDE A LIMITED AREA OF THE CHART WINDOW USING InvalidateRect
    //BECAUSE I DON'T KNOW HOW TO REMOVE BLANKING EFFECTS THAT I SEE ON THE SCREEN
    RECT Rect1=m_chart.m_rectData;
    double nBarWidth = (double)(Rect1.right-Rect1.left)/(double)m_chart.m_nXMax;
    //THE SHIFT (int)(2.5*nBarWidth) IS EMPIRICAL
    Rect1.right= Rect1.left + (int)(nBarWidth*iter)+(int)(2.5*nBarWidth);
    //THE SHIFT -(int)(2.0*nBarWidth) IS EMPIRICAL
    Rect1.left=  Rect1.left + (int)(nBarWidth*iter)-(int)(2.0*nBarWidth);
    //YData FOR THE POINT OF INDEX i1
    int i1=iter-1; if (i1<0) i1=0;
    double nTemp1 = ( 1.0*ThreadData.YData[i1] - m_chart.m_nYMin) *
                        (Rect1.bottom-Rect1.top)/(m_chart.m_nYMax-m_chart.m_nYMin);
    //YData FOR THE POINT OF INDEX i2
    int i2=iter+1; if (i2>=ThreadData.iChartPtNb) i2=ThreadData.iChartPtNb-1;
    double nTemp2 = ( 1.0*ThreadData.YData[i2] - m_chart.m_nYMin) *
                     (Rect1.bottom-Rect1.top)/(m_chart.m_nYMax-m_chart.m_nYMin);
    int ibottom=max(Rect1.bottom - (int)(nTemp1),Rect1.bottom - (int)(nTemp2));
    int itop=min(Rect1.bottom - (int)(nTemp1),Rect1.bottom - (int)(nTemp2));
    Rect1.top =itop-3;
    Rect1.bottom =ibottom+3;
    if (iter==0) {
        m_chart.m_bFullPaint=true;
        m_chart.Invalidate(TRUE);
```

```
    }
    else {
//       m_chart.m_bFullPaint=false;
         m_chart.m_bFullPaint=true;
        ::InvalidateRect(this->m_hWnd,&Rect1,TRUE);
    }
    ////////////////////////////////////////////////////////////////////////////
}
```

The code of the function `CXChart::OnPaint()`, which draws the chart, is displayed in paragraph D.3 page 96.

D Class CXChart

D.1 Declaration

```
class CXChart : public CWnd
{
public:
        CChartPropFrame* m_pPropFrame;
        CStringArray   m_XScaleLabel; // x AXE labels
        int            m_nXLabelStep; // x label step
        bool       m_bShowXScale;     // show x scale
        bool       m_bShowYScale;     // show y scale
        BOOL       m_bShowTitle;      //
        Int        m_nXMax;           // MAX OF THE X AXIS (MIN IS ZERO)
        double     m_nYMax;           // MAX OF THE Y AXIS
        CString    m_YAxeLabelFormat;
        CString    m_XAxeLabelFormat;
        int        m_iXDigitNb;
        int        m_iXDecimaleNb;
        int        m_iYDigitNb;
        int        m_iYDecimaleNb;
        BOOL       m_bShowGridX;
        int        m_GridXLineStyle;
        int        m_TickSizeX;
        int        m_XTextLength;     //LENTGTH (IN PIXELS) OF THE Y AXE LABEL
        double          m_nYMin;      // MIN OF THE Y AXIS
        double     m_nRoundY;         // ROUNDING OF m_nYMax AND m_nYMin. IN OTHER
                                      //WORDS, THE MAX AND MIN OF THE Y AXIS ARE
                                      //MULTIPLE VALUES OF m_nRoundY
        int        m_nYTicks;         // NB OF TICKS ON THE Y AXIS BETWEEN
                                      //m_nYMin AND m_nYMax
        int        m_YTextLength;     //LENTGTH (IN PIXELS) OF THE Y AXE LABEL
        BOOL       m_bAutoScaleY;
        BOOL       m_bShowGridY;
        int        m_GridYLineStyle;
        int        m_TickSizeY;

        CXDataset m_Dataset[MAX_DATASET];// ARRAY OF YDATA SETS
        Int        m_nCountDataset;      // dataset counter
        CString    m_strTitle;           // main title
        CString    m_strYText;           // Y text
        CString    m_strXText;           // X text
        CRect      m_rectUsable;         // usable area
        CRect      m_rectData;           // data area
        CRect      m_rectGraph;          // graph area
        CRect      m_rectXAxis;          // x axis area
```

```
        CRect      m_rectYAxis;          // y axis area
        CRect      m_rectTitle;          // main title area
        CRect      m_rectArea;           // entire control area
        COLORREF   m_clrBkGnd;           // backgroung color
        COLORREF   m_clrDataArea;        // DATA AREA COLOR
        COLORREF   m_clrGraphArea;       // GRAPH AREA COLOR
        COLORREF   BASECOLORTABLE[12];
        COLORREF   m_clrGridVert;      // backgroung color
        COLORREF   m_clrGridHorz;      // backgroung color
        COLORREF   m_clrFrame;         // FRAME COLOR, INCLUDING BASE LINE
        int        m_ThickFrame;       //THICKNESS OF THE LINE TO DRAW THE FRAME
        int HMX_AREA_TITLE;
        int HMX_AREA_YAXIS;            //12           // percentage
        int HMX_AREA_XAXIS;            //11

        int m_iSelectedObject;//OBJECT SELECTED WHEN MOVING THE CURSOR ACROSS THE CHART
        bool m_bFullPaint;    //TO CONTROL THE OnPaint FUNCTION
        double m_OldYMin, m_OldYMax;
```

    etc… Member function declaration here…
}

D.2 Chart construction

As we previously stressed, the charting module plots the arrays of points M(X,Y) with coordinates X=`ThreadData.XData[i]`, and `Y=ThreadData.YData[i]` calculated by the interpreter or the DLL in the simulation thread. We shall use an example to show the way the data are processed the `CXChart` class and the resulting limitations.

Let us assume that the simulation thread builds the following array of equally spaced points {`XData[i]|0≤i<8`} with

```
XData[0]=2.5; XData[1]=5; XData[2]=7.5; XData[3]=10;
XData[4]=12.5; XData[5]=15; XData[6]=17.5; XData[7]=20;
```

The ordinates Ydata[i] play no role at the moment. In this example, the simulation thread calculates eight floating abscissa. However, these values are not stored by the class `CXChart` as floating numbers, but as CStrings in the array m_strXScaleLabel declared as `CStringArray m_XScaleLabel`.

The fact that abscissas are stored as strings means that their values are not considered in the plotting process! In other words, the function `CXChart::DrawXScale`, which plots the X-axis graduation labels, does not care about the values associated to the graduations! You could store anything you want in the arrayl `m_strXScaleLabel`. **`CXChart::DrawXScale` considers that the strings in m_strXScaleLabel must be drawn equally spaced** and therefore, it determines the distance in pixels between two consecutive graduation labels of the X axe. The code in CXChart::DrawXScale (duplicated below) is clear: line 1 counts the number of labels in the array `m_XScaleLabel` and line 3 determines the distance between 2 labels in the rectangle m_rectData. The loop from line 19 to 23 draws the equally spaced labels!

```
bool CXChart::DrawXScale(CDC & dc, BOOL bWMF)
////////////////////////////////////////////////////////////////////////////
//      return      true if ok, else false
////////////////////////////////////////////////////////////////////////////
{
   int nCount = m_XScaleLabel.GetSize();
   if( !nCount ) return false;
```

```
   double nX = (double)m_rectData.Width()/(double)nCount; //DISTANCE BETWEEN 2 GRADUATIONS
////////////////////////////////////////////////////////////////////////////////
   //DRAW THE GRADUATION STRINGS
   int f, nFontSize = (int)(m_rectXAxis.Height()/2.7);           //JHC
   CRect rectTemp;
   const int nBkModeOld = dc.SetBkMode( TRANSPARENT );
   COLORREF color = m_clrFrame, clrOld;
   CPen pen(PS_SOLID, 3, color ), *pPenOld;
   CFont font, *pFontOld;
   font.CreateFont( nFontSize, 0, 0, 0, FW_NORMAL,
               FALSE, FALSE, FALSE, ANSI_CHARSET,
               OUT_TT_PRECIS, CLIP_TT_ALWAYS, PROOF_QUALITY,
               DEFAULT_PITCH, "Arial");
   pPenOld  = dc.SelectObject(&pen);
   pFontOld = dc.SelectObject(&font);
   clrOld   = dc.SetTextColor( color );
   for( f=0; f<nCount; f=f+m_nXLabelStep ) {            // draw text
        rectTemp.top    = m_rectXAxis.top;
        rectTemp.bottom = m_rectXAxis.bottom;
        rectTemp.left   = m_rectXAxis.left + (int)(nX*(f-m_nXLabelStep/2));      //JHC
        rectTemp.right  = m_rectXAxis.left + (int)(nX*(f+1+m_nXLabelStep/2));//JHC
        dc.DrawText(m_XScaleLabel.GetAt(f),rectTemp, DT_CENTER | DT_TOP | DT_SINGLELINE );
    }
    ////////////////////////////////////////////////////////////////////////////////
    //DRAW THE AXIS LABEL
    if( !m_strXText.IsEmpty() ) {
        int nFontXTextSize = (int) (1.4*nFontSize);                 //JHC
        CFont fontXText;
        fontXText.CreateFont( nFontXTextSize, 0, 0, 0, FW_NORMAL,
                        FALSE, FALSE, FALSE, ANSI_CHARSET,
                        OUT_TT_PRECIS, CLIP_TT_ALWAYS, PROOF_QUALITY,
                        DEFAULT_PITCH, "Arial");
        dc.SelectObject(&fontXText);
        if (bWMF) dc.DrawText(m_strXText,m_rectXAxis,
                              DT_CENTER | DT_BOTTOM | DT_SINGLELINE );
         else { //MODIFICATIONS BY JHC; NOW THIS CODE DOES NOT WORK IN A CALL
             // FOR DRAWING A WMF FILE
             CRect MyRect=m_rectXAxis;
             CSize TextSize = dc.GetTextExtent(m_strXText);
             m_XTextLength=TextSize.cx;
             MyRect.left =(MyRect.left+MyRect.right)/2-TextSize.cx/2;
             dc.DrawText( m_strXText, MyRect, DT_LEFT | DT_BOTTOM | DT_SINGLELINE  );
         }
    }
    ////////////////////////////////////////////////////////////////////////////////
    dc.SelectObject(pPenOld);
    dc.SelectObject(pFontOld);
    dc.SetTextColor(clrOld);
    dc.SetBkMode(nBkModeOld);
    return true;
}
```

The point number `nCount` (line 1) is a crucial parameter for `CXChart::DrawXScale`. It is the dimension of the array m_strXScaleLabel, which is constructed in the loop extending from line 11 to 15, (especially line 14) of the function `CAGNTView::DrawChart`. This loop shows that: `nCount=ThreadData.iChartPtNb`.

Line 13 in `CAGNTView::DrawChart` fomats the abscissa. Let us consider that we want to pass XData[0]=31.21. It is possible to use the following various formats:

Format for floats or double XData[0]=31.21	Result
`sBuffer.Format("%f2",XData[0])`	31.21 (2 numbers following the dot)
`sBuffer.Format("%5.1f",XData[0])`	31.2 (5 chars, including 1 number after the dot

sBuffer.Format("%5d3",XData[0])	3.121E000
Format for integer XData[0]=312	
sBuffer.Format("%d",XData[0])	312

D.3 Chart painting

Chart painting is executed by the member function **void** CXChart::OnPaint(). The Boolean variable m_bFullPaint is used to partly repaint the chart, in order to avoid some blanking effects.

```
void CXChart::OnPaint()
////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////
{
  CPaintDC dc(this); // device context for painting
  if (m_bFullPaint) {
       if (m_bAutoScaleY) AutoScaleY();      //AUTOMATIC DETERMINATION OF m_nRoundY
       CalcDatas();
       m_nYTicks=(int)((m_nYMax-m_nYMin)/m_nRoundY);
       PaintBkGnd( dc );
      PaintDataArea( dc );            //THE AREA CONTAINING THE DATA POINTS
      DrawTitle( dc );
     ////////////////////////////////////////////////////////////////////////////
      if (m_bShowGridX) DrawVertLine( dc );
      DrawTicksX(dc);
      if (m_bShowGridY) DrawHorzLine( dc );
      DrawTicksY(dc);
     ////////////////////////////////////////////////////////////////////////////
      DrawFrame(dc);
      DrawBaseline( dc );
      DrawAxes( dc );
      DrawYScale( dc );
      DrawXScale( dc );
     ////////////////////////////////////////////////////////////////////////////
      DrawDatasets( dc );
     ////////////////////////////////////////////////////////////////////////////
  }
  else {
  //      CalcDatas();
      PaintBkGnd( dc );
      PaintDataArea( dc );            //THE AREA CONTAINING THE DATA POINTS
      m_nYTicks=(int)((m_nYMax-m_nYMin)/m_nRoundY);
      DrawTitle( dc );
      DrawGrid( dc );
      DrawBaseline( dc );  //
      DrawAxes( dc );
      DrawYScale( dc );
      DrawXScale( dc );
      DrawDatasets( dc );
  }
}
```

D.4 Chart customization & Property pages

To customize the chart, first select a chart element (curve, label, grid line, axe….). In other words:

- Move the cursor onto the element. The cursor should switch from a cross to a hand when the element is identified by the program. This property is controlled in the member function `CXChart::OnMouseMove`.
- Then, left click the mouse. This operation fires the property page containing the controls to customize the selected element. There are four property pages (`CChartPropPage1`, `CChartPropPage2`,…) which are elements (i.e., member variables) of the class `.CChartPropSheet`.

  For instance, if you select an axe by clicking an axe of the chart, the program activates the second page (`CChartPropPage2`), which contains the controls to customize the axes. Moreover, clicking another chart element when one property page is selected switches to another page if necessary.

There are three active property pages, which are displayed in Fig. 30 and Fig. 31 below. The actions selected in the property pages are instantaneously executed to update the chart display. This property is achieved by repainting the chart window with the function `m_chart.Invalidate()` which executes `m_chart.OnPaint()`.

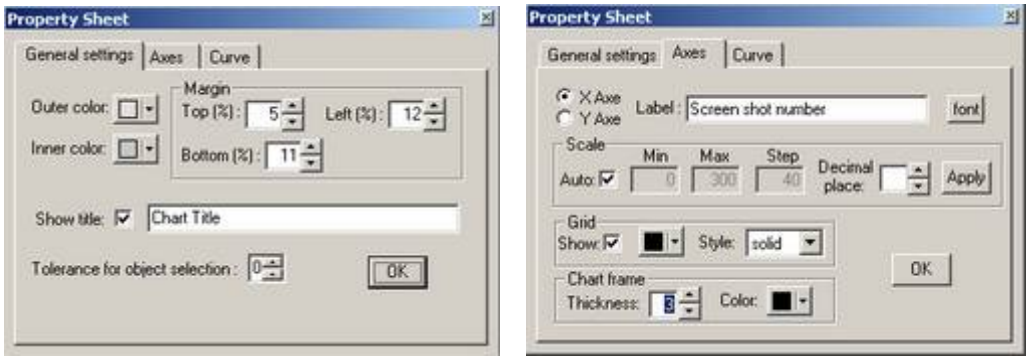


Fig. 30

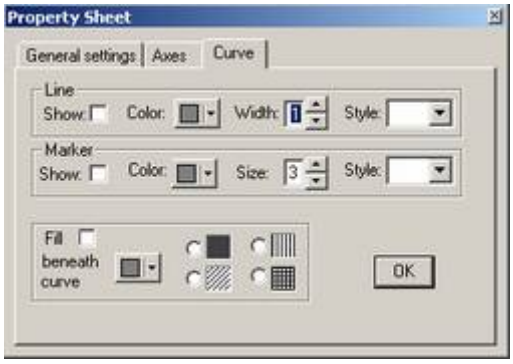


Fig. 31

The chart customization is straightforward. Fig. 32 shows two different charts of the same data.

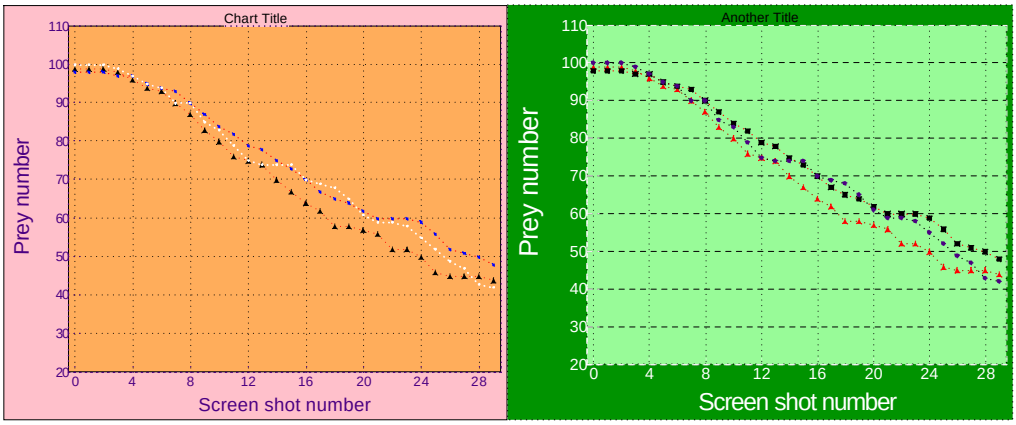


Fig. 32: Examples of customization of the same chart

D.5 Saving charts and chart parameters

- Chart parameters are saved in the scenario file. Thus, simply open the FileSave dialog box (click the left-bar buttom), as save to a file with extension MAS.
- A chart can be copied to the clipboard to generate a WMF image. This property is controlled by the code in `CMainFrame:: OnCopyToWMFButton()`. Fig. 23 page 84 was inserted in this document following this procedure. To copy the chart to the clipboard, simply click the button in the left bar.

E Class CXDataSet

Chapter 6

History: last revision April 2006

Population initialization: DRAFT

The module DRAFT is used to define graphically (almost) any initial configuration of agents and obstacles in the simulation terrain.

Functionally, DRAFT is a vectorial drawing tool integrated in MASS to generate visually the initial populations of obstacles and agents in the terrain. From the programmation point of view, DRAFT is an instance of the class CXDraft declared as shown in the header below.

```
class CXDraft : public CWnd
{
   public:
      CLine*      m_Line;             //ARRAY OF LINES DRAWN IN THE WINDOW
      int         iLineNb;            //NB OF DRAWN LINES
      int         iSelectedLine;      //INDEX OF THE SELECTED LINE (IF ANY)
      CRectangle* m_Rect;             //ARRAY OF RECTANGLES DRAWN IN THE WINDOW
      int         iRectNb;            //NB OF DRAWN RECTANGLES
      int         iSelectedRect;      //INDEX OF THE SELECTED RECTANGLE (IF ANY)
      CPolyLine*  m_PolyLine;         //ARRAY OF POLYLINES DRAWN IN THE WINDOW
      int         iPolyLineNb;        //NB OF DRAWN POLYLINES
      int         iSelectedPolyLine;  //INDEX OF THE SELECTED POLYLINES (IF ANY)
      bool        bPolyInProgress;    //true AFTER FIRST POINT OF THE POLYLINE
      CPolygone*  m_Polygone;         //ARRAY OF POLYGONES DRAWN IN THE WINDOW
      int         iPolygoneNb;        //NB OF DRAWN POLYGONES
      int         iSelectedPolygone;  //INDEX OF THE SELECTED POLYGONE (IF ANY)
      bool        bPolygoneInProgress;//true AFTER FIRST POINT OF THE POLYGONE
      int         iDistMax;           //MAXMIMUM DISTANCE TO SELECT AN OBJECT
      int         iSelectMode;        //SELECMODE OF THE SELECTED OBJECT.
                                      //ABOVE IN THE HEADER
      CWnd*       pParent;      //POINTER TO THE PARENT WINDOW
      RECT        m_InitRec;    //RECT STRUCTURE TO STORE THE INITIAL WINDOW SIZE
      JHCButton   JButton1,JButton2,JButton3,JButton4,JButton5;
      JHCButton   JButton6,JButton7,JButton8,JButton9,JButton10;
      JHCButton   JButton11,JButton12,JButton13,JButton14,JButton15;
      bool        bShowButton;      //false: HIDE THE APPLICATION BUTTONS
      CPoint      m_FromPt, m_ToPt;
      CPoint      OldMousePoint;
      int         m_iLineStyle,m_iLineWidth;
      bool        m_bDraw;
```

```
        CString     OpenFileName;
        bool        bModified;
        int         DSquare;
         etc…
}
```

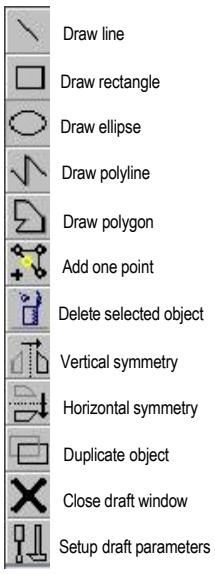
Script 16

Thus:

- `DRAFT` is encapsulated in a window class `CXDraft` derived from the class `CWnd`.
- This class contains the graphical objects (lines, rectangles, polygons..) drawn by the user, as we describe below. This class organization decouples most draft properties from those of the host application.
- `DRAFT` is integrated in the **CORE** as the member object `CXDraft m_draft` of the parent class `CAGNTView`.

The `DRAFT` window opens on top of its parent windows `CAGNTView`. To fire the `DRAFT` window, simply click the Draft icon in the left toolbar. This action executes the function `void CAGNTView::OnToolbarDraft()`, which calls `CAGNTView::CreateDraftWnd()`, which build the draft windows through the member function:

```
BOOL CXDraft::CreateDraft(HWND ParenthWnd,     //PARENT
                          bool bEnable)//false= HIDDEN AT CREATION
```



Left draft toolbar

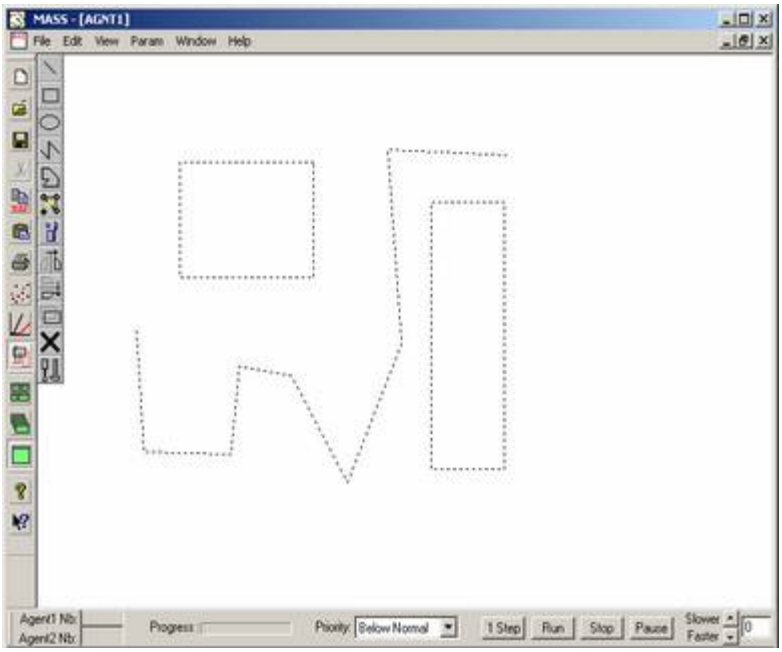


Fig. 33: typical DRAFT window; Note the additional vertical bar including the CHART tools to drawn and modified objects, which are represented in the window

The presence of the `DRAFT` window is revealed by the change or the mouse pointer (which switches from an arrow to a cross) and also by the appearance of an additional left toolbar (to draw, erase, move and modify the objects) as shown in Fig. 33.

The procedure for defining agents and obstacles in the terrain is the following:

- First, it is necessary to define and customize objects in the terrain: lines, rectangles, ellipses, polylines, polygons and the background. An object represents a zone in the terrain. Creating an object amount to creating an empty envelope that will be filled up with agents or obstacles.

  If there is no line, rectangle, ellipse, polyline, nor polygon, the sole object is the background that contains all the terrain points. In other words, the background is the complement with respect to the terrain of all other objects, i.e., the set of "all terrain cells, which are not in the other objects".
- Second select an existing object. Perhaps, customize again the object shape.
- Third, fill the selected object with agents and (or) obstacles. Filling the background object consists in filling the terrain area outside the other objects.

In this framework, it is possible to define as much objects as necessary, and to customize separately the number of agents and the number of obstacles inserted in each object, inside the object (for rectangles, ellipses, polygons, and the terrain) and (or) in the border (for all objects except the terrain).

A Object creation

A.1 class CPointEx

The point is the basic object. A line, a rectangle or an ellipse are defined with two points. For the line, the 2 points are the end points. For a rectangle or an ellipse, the 2 points are the top-left corner and the right-bottom corner. A polyline is represented by a set of N points. The header of the `Class CpointEx` header is as follows:

```
class CPointEx
{
public:
      double x;
      double y;
...
}
```

It is important to stress that points are defined with relative coordinates. For instance the points of coordinates (x=0,y=0) and (x=1,y=1) are respectively located in the top left and the bottom right corners of the client window. One complication comes from the fact that each point must be represented in the screen (for display) and in the terrain (for simulation).

The typical code to derive the screen coordinates (Xpos, Ypos) of an object (agent or obstacle) from its relative coordinates (x,y) is the following one:

```
RECT rect;
GetParent()->GetClientRect(&rect);
double XCoef= rect.right-rect.left;
double YCoef= rect.bottom-rect.top;
int Xpos= (int) (x*(rect.right-rect.left));
int Ypos= (int) (y*(rect.bottom-rect.top));
```

The typical code to derive the cell coordinates (XCell, YCell) in the terrain of an object (agent or obstacle) from its relative coordinates (x,y) is the following one:

```
int XCell= (int) (x*XDim);
int YCell= (int) (y*YDim);
```

where XDim and YDim are the number of cells in the X and Y directions respectively.

A.2 class CLine

We diplay below the header of the class Cline.

```
class CLine
{
    public:
    int           iWidth;
    COLORREF      iColor;
    COLORREF      ColorRef[2];
    int           iStyle;
    CPointEx      P0,P1;          //END POINTS OF THE LINE
    int           iSelectMode;    //  -2: THE LINE IS NOT SELECTED
                                  //  -1: THE LINE IS SELECTED BUT NO POINT IS SELECTED
                                  //   0: POINT OF INDEX 0 IS SELECTED
                                  //   1: POINT OF INDEX 1 IS SELECTED
    int           DSquare;        //SIZE OF THE SQUARE AROUND THE ENDS WHEN HIGHLIGHTED

    CPointEx*     AgentCell[AGENTTYPENB];
    int           iAgentNb[AGENTTYPENB];
    int           iAgentGenMode[AGENTTYPENB];//GENERATION MODE FOR EACH AGENT TYPE
                                             //   =0 :Random
                                             //   =1 :Line filled up (I.E., SATURATED)
                                             //   =2 :Equally spaced points
    CPointEx*     ObstacleCell;
    int           iObstacleNb;
    int           iObstacleGenMode;
    //VARIABLES TO CONTROL THE OBJECT CREATION DIALOG BOX
    int         iSelectedAType;      //AGENT SELECTED IN THE OBJECT CREATION BOX
    bool        bAgentSelected;      //true WHEN AGENT SELECTED IN OBJECT CREATION BOX
    etc…
```

The grayed lines show that a Cline object includes populations of agents and obstacles, which are represented by arrays of points, the number of elements of which are adjusted at run time and stored in the arrays iAgentNb and IObstacleNb. The conditions of generations are also specified at runtime and stored in the arrays iAgentGenMode and iObstacleGenMode.

To create and customize a new line, i.e., an instance of the Cline:

- Click the line button in the left toolbar.
  7) This action triggers the button function JHCButton::OnLButtonDown as all buttons of the left draft toolbar in Fig. 33 page 101 are instances of the class JHCButton. The description of the button class is postponed to paragraph A.8 page 107.
  8) JHCButton::OnLButtonDown sends a message to ist parent window (i.e. to CXDraft), which executes its member fucntion LRESULT CXDraft::OnClickBitmap.
- Then move the cursor to the line starting point, depress the left button of the mouse (left button down).
  9) This operation triggers the function CXDraft::OnLButtonDown which executes CXDraft::ExtendLineArray to extend the member array m_Line. Thus, the dimension of this array is dynamically updated at runtime depending on the number of lines drawn in the window. The number of lines is iLineNb (see the declaration in the header CXDraft, page 101).

10) It also sets up the starting point `P0` coordinates in the `Cline` object. Keep the left button down!

- Move to the final point of the line. Then, release the left button (left button up). This operation sets up the end point `P1` coordinates in the `Cline` object.
- To stop the line drawing operation, click again the line icon or depress another icon in the left toolbar

In the present version, we chose to draw all objects with the same color selected in the dialog box fired by the icon . The relevant variables are `COLORREF CTranspWnd.iDefaultDrawPen` and `CTranspWnd.iDefaultLineStyle`.

A.3 class Crectangle

```
class CRectangle
{
public:
    int           iWidth;
    COLORREF      iLineColor;
    int           iLineStyle;
    //RELATIVE COORDINATES OF THE TOP-LEFT AND RIGHT-BUTTON CORNERS OF THE RECTANGLE.
    //COORDINATES ARE RELATIVE TO THE DISPLAY WINDOW OF MASS. FOR INTANCE left=0.5
    //AND top=0.5, MEANS THAT THE TOP-LEFT CORNER OF THE RECTANGLE IS IN THE MIDDLE
    //OF THE CView WINDOW.
    double        left;
    double        top;
    double        right;
    double        bottom;
    int           iSelectMode;
    int           DSquare;//SIZE OF THE SQUARE AROUND THE ENDS WHEN HIGHLIGHTED
    //ARRAY REPRESENTING THE RELATIVE POSITION OF AGENTS IN THE RECTANGLE.
    //FOR INSTANCE AgentCell[0][3].x=0.5 MEANS THAT THE AGENT iAType=0 OF INDEX 3
    //IN THE ARRAY IS IN THE MIDDLE OF THE CView WINDOW, NOT IN THE MIDDLE OF THE
    //THIS RECTANGLE.
    //THUS left<=AgentCell[i][j].x<right AND top<=AgentCell[i][j].y<bottom
    CPointEx*     AgentCell[AGENTTYPENB];
    int           iAgentNb1[AGENTTYPENB];  //NB OF AGENTS OF EACH TYPE
    int           iAgentNb2[AGENTTYPENB];  //NB OF AGENTS USED TO PLOT A SQUARE LATTICE
    int       iAgentGenMode[AGENTTYPENB];  //GENERATION MODE FOR EACH AGENT TYPE
    //                                              =0 :Inside random
    //                                              =1 :Border random
    //                                    =2 :Border filled up (I.E., SATURATED)
    //                                    =3 :Generation of a square lattice
    //ARRAY REPRESENTING THE RELATIVE POSITION OF OBSTACLES IN THE RECTANGLE.
    //FOR INSTANCE ObstacleCell[3].x=0.5 MEANS THAT THE OBSTACLE OF INDEX 3
    //IN THE ARRAY IS IN THE MIDDLE OF THE CView WINDOW, NOT IN THE MIDDLE OF THE
    //THIS RECTANGLE
    CPointEx*      ObstacleCell;
    int            iObstacleNb1;     //NUMBER OF OBSTACLES IN THE ELLIPSE
    int            iObstacleNb2;     //NUMBER OF OBSTACLES IN THE ELLIPSE
    int            iObstacleGenMode; //GENERATION MODE OF OBSTACLES IN THE ELLIPSE
    //VARIABLES TO CONTROL THE OBJECT CREATION DIALOG BOX
    int            iSelectedAType;   //AGENT SELECTED IN THE OBJECT CREATION BOX
    bool           iAgentSelected;   //true WHEN AGENT SELECTED IN OBJECT CREATION BOX
etc…
}
```

Note that 2 numbers are associated to each object population. For instance the number of agents `iAType=0` is defined by the numbers `iAgentNb1[0]` and `iAgentNb2[0]`. The use of this numbers depends on the selection mode of the objects. If `iAgentGenMode[0]` equals 0 (fill random), 1 (fill border random), or 2 (fill full border), the number of agents is simply `iAgentNb1[0]`. However, when `iAgentGenMode[0]`=3, corresponding to the generation of a rectangular lattice of objects in the rectangle, the number of agents is `iAgentNb1[0]* iAgentNb2[0]`.

To create and customize a new rectangle, i.e., an instance of the `CRectangle`:

- Click the line button in the left toolbar.

  11) This action triggers the button function `JHCButton::OnLButtonDown` as all buttons of the left draft toolbar in Fig. 33 page 101 are instances of the class `JHCButton`. The description of the button class is postponed to paragraph A.8 page 107.

  12) `JHCButton::OnLButtonDown` sends a message to ist parent window (i.e. to `CXDraft`), which executes its member fucntion `LRESULT CXDraft::OnClickBitmap.`
- Then move the cursor to the rectangle starting point, depress the left button of the mouse (left button down).

  13) This operation triggers the function `CXDraft::OnLButtonDown` which executes `CXDraft::ExtendRectangleArray` to extend the member array `m_Rect`. Thus, the dimension of this array is dynamically updated at runtime depending on the number of lines drawn in the window. The number of lines is `iRectNb` (see the declaration in the header `CXDraft`, page 101).

  14) It also sets up the starting point coordinates (`left`,`top`) in the `CRectangle` object. Keep the left button down!
- Move to the final point of the line. Then, release the left button (left button up). This operation sets up the end point coordinates (`right`, `bottom`) in the `Cline` object.
- To stop the rectangle drawing operation, click again the line icon or depress another icon in the left toolbar

A.4 class CEllipse

```
class CEllipse
{
public:
    //VARIABLES REPRESENTING THE ELLIPSE POSITION, STYLE, COLOR....
    int        iWidth;
    COLORREF   iLineColor;
    int        iStyle;
    double     left;
    double     top;
    double     right;
    double     bottom;
    int        iSelectMode;
    int        DSquare;//SIZE OF THE SQUARE AROUND THE ENDS WHEN HIGHLIGHTED
    //VARIABLES REPRESENTING THE POPULATIONS OF OBJECTS IN THE ELLIPSE
    //CELLS OF THE AGENT IN THE TERRAIN FOLLOWING THEIR CREATION IN THE ELLIPSE
    //FOR INSTANCE AgentCell[0][3].x IS THE X COORDINATE OF THE CELL CONTAINING THE
    //AGENT iAType=0, AND OF INDEX 3.
    //WARNING: AgentCell[0][3].x IS AN INTEGER! THE POSITION IN THE TERRAIN AND
    //IT IS CALULATED USING DE DIMENSION XDim OF THE TERRAIN IN THE X DIRECTION
    CPointEx*  AgentCell[AGENTTYPENB];
    int        iAgentNb[AGENTTYPENB];       //NB OF AGENTS OF EACH TYPE
```

```
    int         iAgentGenMode[AGENTTYPENB];  //GENERATION MODE FOR EACH AGENT TYPE
    //CELLS OF THE OBSTACLES IN THE TERRAIN FOLLOWING THEIR CREATION IN THE ELLIPSE
    //FOR INSTANCE ObstacleCell[3].x IS THE X COORDINATE OF THE CELL CONTAINING THE
    //OBSTACLE OF INDEX 3.
    CPointEx*   ObstacleCell;
    int         iObstacleNb;           //NUMBER OF OBSTACLES IN THE ELLIPSE
    int         iObstacleGenMode;      //GENERATION MODE OF OBSTACLES IN THE ELLIPSE
    //VARIABLES TO CONTROL THE OBJECT CREATION DIALOG BOX
    int         iSelectedAType;   //AGENT SELECTED IN THE OBJECT CREATION BOX
    bool        bAgentSelected;   //true WHEN AGENT SELECTED IN OBJECT CREATION BOX
```

etc…

To create and customize a new ellipse, i.e., an instance of the `CEllipse`:

- Click the line button in the left toolbar.
- Follow the same procedure as that described for drawing a rectangle. The update of the ellipse array is also identical to that described for rectangles.

A.5 class CPolyLine

```
class CPolyLine
{
public:
    int         iWidth;
    COLORREF    iLineColor;
    int         iStyle;
    CPointEx*   LinePt;
    int         iLinePtNb;
    int         iSelectMode; //-2<=iSelectMode<iLinePtNb
    BOOL        bShow;       //BOOL VARIABLE TO SHOW OR HIDE THE OBJECT. SEE WGShowObject
    bool        bSelect;     //BOOL VARIABLE TO SHOW OR HIDE THE OBJECT. SEE WGShowObject
    int         DSquare;     //SIZE OF THE SQUARE AROUND THE ENDS WHEN HIGHLIGHTED
    //VARIABLES REPRESENTING THE POPULATIONS OF OBJECTS IN THE ELLIPSE IN RELATIVE
    //COORDINATES
    CPointEx*    AgentCell[AGENTTYPENB];
    int          iAgentNb[AGENTTYPENB];         //NB OF AGENTS OF EACH TYPE
    // POSSIBLE VALUE iAgentGenMode[i]=0 :Inside random
    //                               =1 :Border filled up (I.E., SATURATED)
    int          iAgentGenMode[AGENTTYPENB];    //GENERATION MODE FOR EACH AGENT TYPE
    CPointEx*    ObstacleCell;
    int          iObstacleNb;         //NUMBER OF OBSTACLES IN THE ELLIPSE
    int          iObstacleGenMode;    //GENERATION MODE OF OBSTACLES IN THE ELLIPSE
    //VARIABLES TO CONTROL THE OBJECT CREATION DIALOG BOX
    int          iSelectedAType;      //AGENT SELECTED IN THE OBJECT CREATION BOX
    bool         bAgentSelected;      //true WHEN AGENT SELECTED IN OBJECT CREATION BOX
```

etc…

The number of polylines in `CXDraft`, i.e, the dimension of the array `m_BrokLine` is `iPolyLineNb` (see the declaration in the header `CXDraft`, page 101). The dimension of this array is dynamically updated at runtime depending on the number of broken lines drawn in the transparent window.

The method to draw polylines or polygons slightly differs from that described for lines, rectangles or ellipses. As previously, you must first select the polyline or the polygon button. Then:

- Click the screen at the starting point of the polyline. "Click" means left button down and up. This operation triggers the function `CXDraft:: OnLButtonDown`, which executes

CXDraft::ExtendPolyLineArray to extend the member array m_PolyLine. Thus, the dimension of this array is dynamically updated at runtime depending on the number of polylines drawn in the window. Note that you need not keeping the left button down when you move the cursor to the location of the second point.

- Click again (left button down and up) to add one point to the polyline or the polygon. This operation triggers the function CXDraft:: OnLButtonDown, which executes CXDraft::ExtendPolyLineArray to extend the number of points in the polyline under construction.
- Repeat this operation for the other points of the polyline. Right click to generate the last point.

A.6 class CPolygone: public CPolyLine

CPolygon is derived from CPolyLine. Note that:

- Polylines and polygons are defined as arrays of points.
- Each object (line, rectangle, brokenline, polygon) includes a member variable iSelectMode. This variable is a flag with the following possible values :
- iSelectMode=-2: Object is not selected
  =-1: Object is selected as a whole, no point is selected.
  = 0: The point of index 0 is selected
  = 1: The point of index 1 is selected, and so on…

The number of polygons in CXDraft, i.e, the dimension of the array m_Polygone is iPolygoneNb (see the declaration in the header CXDraft, page 101). The dimension of this array is dynamically updated at runtime depending on the number of polygones drawn in the window.

The method to draw polygons is identical to that described in the previous paragraph to draw polylines, except that you need click the polygon button to start the draft.

A.7 class CBackground

```
public:
     CPointEx*   AgentCell[AGENTTYPENB];
     int         iAgentNb[AGENTTYPENB];      //NB OF AGENTS OF EACH TYPE
     int         iAgentGenMode[AGENTTYPENB];//GENERATION MODE FOR EACH AGENT TYPE
     CPointEx*   ObstacleCell;
      int        iObstacleNb;         //NUMBER OF OBSTACLES IN THE ELLIPSE
      int        iObstacleGenMode;    //GENERATION MODE OF OBSTACLES IN THE ELLIPSE
      //VARIABLES TO CONTROL THE OBJECT CREATION DIALOG BOX
      int        iSelectedAType;      //AGENT SELECTED IN OBJECT CREATION BOX
      bool       bAgentSelected;      //true WHEN AGENT SELECTED IN OBJECT CREATION BOX
      int        iAgentSize;
```

A.8 class JHCButton : public CWnd

Recall that the class CXDraft includes 16 button objects (JButton1, JButton2,… JButton16) derived from the class JHCButton. Most of this buttons are used to add new graphic objects to CXDraft as described in the previous paragraphs. The header is displayed below:

```
class JHCButton : public CWnd
{
public:
        CBitmap m_bitmap1,m_bitmap2;
        int m_ID;
        bool bState;
        JHCButton();   // Construction
        void Create(int iLeft, int iTop, int iWidth, int iHeight,
                    CWnd* pParent,int ID_BITMAP1,int ID_BITMAP2,int nID);
        void  ResetBitmap();
protected:
        //{{AFX_MSG(JHCButton)
        afx_msg void OnLButtonDown(UINT nFlags, CPoint point);
        afx_msg void OnLButtonUp(UINT nFlags, CPoint point);
        afx_msg void OnPaint();
        //}}AFX_MSG
        DECLARE_MESSAGE_MAP()
};
```

A8.1 Button creation

The class `JHCButton` is used to create the buttons which are displayed in the left draft toolbar (see Fig. 33 page 101). Recall that the buttons are created through the function `JButton1.Create` when the XDRAFT windows is created through the function call:

```
BOOL CXDraft::CreateDraft(HWND ParenthWnd,   //PARENT
                          bool bEnable)      //false= HIDDEN AT CREATION
////////////////////////////////////////////////////////////////////////////
//CONSTRUCTOR FOR A DRAFT WINDOW THAT COVERS THE FULL CLIENT AREA OF ITS PARENT
////////////////////////////////////////////////////////////////////////////
{
    CString NEWCLASS1=AfxRegisterWndClass(0,
                                          AfxGetApp()->LoadStandardCursor(IDC_CROSS),
                                          (HBRUSH) ::GetStockObject(WHITE_BRUSH),
                                          0);
    if (CreateEx(WS_EX_CONTEXTHELP,
                 NEWCLASS1,            //WINDOW CLASS NAME
                 "Transp",             //WINDOW NAME
                 WS_CHILD |            //CHILD WINDOW; STAYS IN THE PARENT WINDOW
                 WS_MAXIMIZE,          //OCCUPY FULL PARENT CLIENT AREA
                 0,0,0,0,
                 ParenthWnd,
                 0,
                 NULL) == FALSE) {
        MessageBox("FAIL TO CREATE CXDraft WINDOW","FROM CreateDraft",MB_OK);
        return FALSE;
    }
    ////////////////////////////////////////////////////////////////////
    JButton1.Create(0,0,25,25, this,IDB_BITMAP1, IDB_BITMAP2,0);   //LINE
    JButton2.Create(0,24,25,25, this,IDB_BITMAP3, IDB_BITMAP4,1);  //RECTANGLE
    JButton3.Create(0,48,25,25, this,IDB_BITMAP5, IDB_BITMAP6,2);  //ELLIPSE
    JButton4.Create(0,72,25,25,this,IDB_BITMAP7, IDB_BITMAP8,3);   //BROKENLINE
    JButton7.Create(0,96,25,25,this,IDB_BITMAP13,IDB_BITMAP14,6);  //POLYGONE
    JButton8.Create(0,120,25,25,this,IDB_BITMAP15,IDB_BITMAP16,7); //ADD A POINT IN LINE
    JButton9.Create(0,144,25,25,this,IDB_BITMAP17,IDB_BITMAP18,8); //DELETE SELECTED OBJECT
    JButton11.Create(0,168,25,25,this,IDB_BITMAP21,IDB_BITMAP22,10);  //VERTICAL SYMMETRY
    JButton12.Create(0,192,25,25,this,IDB_BITMAP23,IDB_BITMAP24,11);  //HORIZONTAL SYMMETRY
    JButton13.Create(0,216,25,25,this,IDB_BITMAP25,IDB_BITMAP26,12);  //DUPLICATE SELECTED OBJECT
    JButton10.Create(0,240,25,25,this,IDB_BITMAP19,IDB_BITMAP20,9);   //CLOSE WINDOW
    JButton16.Create(0,264,25,25,this,IDB_BITMAP27,IDB_BITMAP28,13);  //DRAW PARAMETERS SETTING
    ////////////////////////////////////////////////////////////////////
```

```
    ::GetClientRect(ParenthWnd,&m_InitRec);
    ////////////////////////////////////////////////////////////////////////
    EnableWindow(bEnable);            //HIDE OR SHOW AT CREATION
    return TRUE;
}

void JHCButton::Create(int iLeft, int iTop, int iWidth, int iHeight,
                       CWnd* pParent,
                       int ID_BMP1,  //IDENTIFIER OF THE DEFAULT BUTTON BITMAP
                       int ID_BMP2,  //IDENTIFIER OF THE DEPRESSED-BUTTON BITMAP
                       int nID)
////////////////////////////////////////////////////////////////////////////
// HERE IS THE ONLY WEAKNESS OF THE JHCButton CLASS: YOU MUST INSERT THE BITMAPS
// OF THE BUTTON IN THE RESOURCE OF THE APPLICATION.
// USE THE RESOURCE EDITOR OF VISUALC TO INCLUDE THE BITMAP IN THE RESOURCE FILE
// ID_BMP1 IS THE IDENTIFIER IN THE RESOURCE FILE OF THE DEFAULT-BITMAP OF THE BUTTON
////////////////////////////////////////////////////////////////////////////
{
    m_ID=nID;
    if ((!m_bitmap1.LoadBitmap(ID_BMP1)) || (!m_bitmap2.LoadBitmap(ID_BMP2))) {
        ::MessageBox(NULL,"CANNOT OPEN BITMAP","",MB_OK);
        return;
    }
    RECT rect;
    rect.left=iLeft; rect.top=iTop;
    rect.right=iLeft+iWidth; rect.bottom=iTop+iHeight;
    CString NEWBUTTON=AfxRegisterWndClass(0,AfxGetApp()->LoadStandardCursor(IDC_ARROW),
                                          (HBRUSH) ::GetStockObject(LTGRAY_BRUSH),0);
    CWnd::Create(NEWBUTTON,"",WS_CHILD|WS_VISIBLE,rect,pParent,0,NULL);
}
```

A8.2 Button Click

B Object selection & customization

B.1 Selection

Selecting an object makes it possible to modify its topology (if it is free of agents or obstacles) or to populate it. `m_pdraft` controls the selection or deselection of the different “populations” of objects by executing the member functions `CXDraft::OnLButtonDown`, `CXDraft::OnMouseMove`, and `CXDraft::OnLButtonUp`, which are trigged by the action of the left mouse button. The flowchart is represented in Fig. 34.

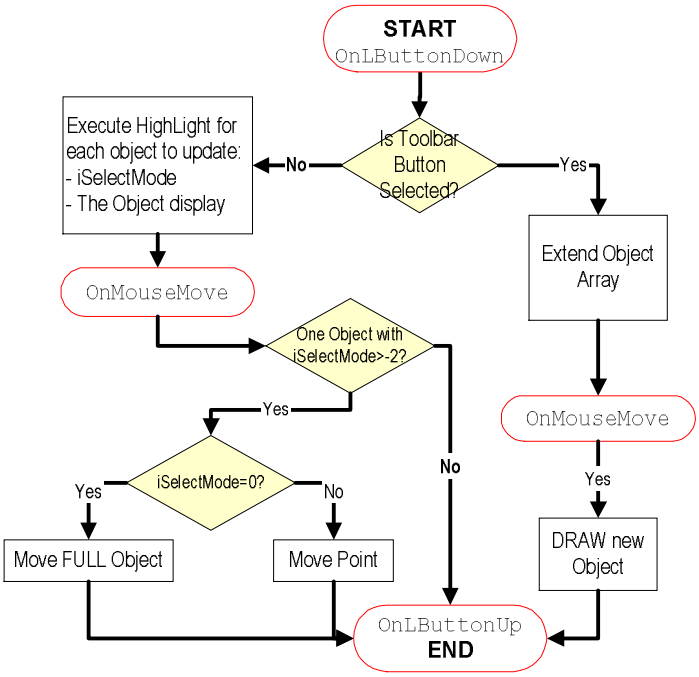


Fig. 34: Flowchart of the cycle induced by depressing, moving and releasing the left mouse button.

when the left button of the mouse in depressed in the draft window, the class `CXDraft` executes it members function `CXDraft::OnLButtonDown()`.There are two cases :

Case 1: If one draft button is selected in the left toolbar (see), the module starts drawing an object as decribed in the section A page 102.

Case 2: If no draft button is selected, each existing object in `CXDraft` executes its function `Highlight`. Indeed, all objects (lines, rectangle, ellipses, etc…) have a member function `HighLight`, which determines the reaction of the object following the click of the left mouse button.

```
void CLine::HighLight(CDC* pDC, RECT rect, CPoint Pt, int DistMax)
void Crectangle::HighLight(CDC* pDC,RECT rect,CPoint Pt,int DistMax);
void CPolyLine::HighLight(CDC* pDC,RECT rect,CPoint Pt,int DistMax);
void Cpolygone::HighLight(CDC* pDC,RECT rect,CPoint Pt,int DistMax);
```

The call parameter `Pt` must be the position of the pointer in the screen.

The flowchart of the `HighLight` function is represented in Fig. 35. It setups the selection parameter `iSelectMode` of the object. The following values are possible:

- Single-point selection: This case occurs when the mouse pointer is very close to a point of the object. In that case `iSelectMode=k` where `k` is the point index in the array of points constituting the agent.
- Full-object selection: `iSelectMode=-1`. This case when the mouse pointer is close to the object without being close to a specific point constituting the object
- Deselection: `iSelectMode=-2`. When the pointer position is too far from the object.

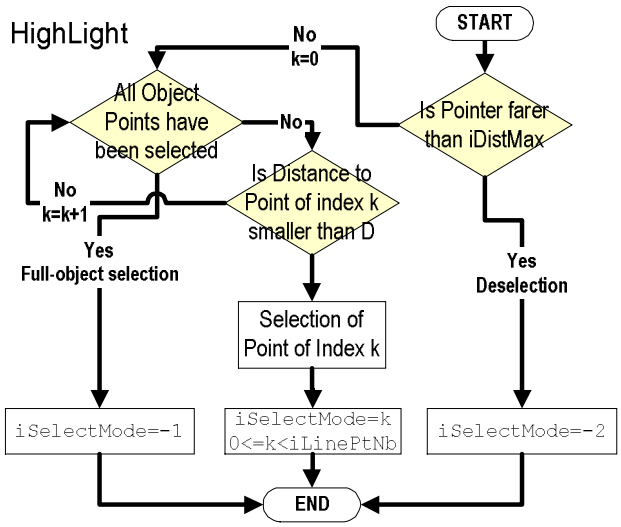


Fig. 35: Flowchart of `Highlight` function

B.2 Deletion

Deleting an object is executed by the function `CXDraft::OnObjectDelete()`. It consists of:

- Erasing the object in the screen. Writing of erasing an object in the screen are executed by the member functions `InvertHighlight` for each object. In other words, if the object is not drawn it is drawn, and if it is drawn, it is erased. The trick to achieve this dual property with the same function consists in defining the context device as follows for all drawing operations:

```
////////////////////////////////////////////////////////////////////////
CClientDC dc(this);
CPen* penCur = new CPen(this->iDefaultLineStyle,1,this->iDefaultDrawPen);
dc.SelectObject(penCur);
dc.SetROP2(R2_NOTXORPEN);
////////////////////////////////////////////////////////////////////////
```

- Deleting the object in the memory. The deletion in memory forces to shrink an array of objects, the line array, or the rectangle array, or the Ellipse array….

```
void CXDraft::OnObjectDelete()
////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////{
       if (iSelectedLine>-1)         ShrinkLineArray();
       if (iSelectedRect>-1)         ShrinkRectangleArray();
       if (iSelectedEllipse>-1)      ShrinkEllipseArray();
       if (iSelectedPolyLine>-1)     ShrinkPolyLineArray();
       if (iSelectedPolygone>-1)     ShrinkPolygoneArray();
       GetTotalObjectNb();
}
```

B.3 Customization

B3.1 Line customzation

To modify an existing line:

- First select the line by left clicking the line with the mouse (button down, see paragraph B.1). Il you click one end point, you select specifically this end point. Note that in the selected mode, the line end points are decorated with two small squares. Then, you can move globally the line (or the selected end point, depending on the selection mode) by moving the mouse (remember that the left button is down during this operation). To move very accurately the line, use the direction keys of the keypad (UP, LEFT, RIGHT, or DOWN), once the line has been selected.
- To operate a vertical symmetry, select the line and click the icon in the left toolbar. This action executes the function `CXDraft::Horinzontal Symmetry()`.
- To operate a vertical symmetry, select the line and click the icon in the left toolbar. This action executes the function `CXDraft::Vertical Symmetry()`.
- To duplicate a line, select the line and click the icon in the left toolbar. This action executes the function `CXDraft::DuplicateObject()`.
- To delete a line, select the line and click the icon in the left toolbar.
- When an object is selected (with `CXDraft::OnLButtonDown`), the corresponding family flag is switched to the index of the object, i.e., its rank in the corresponding array. For instance, if no polygon was selected,, `iSelectedPolygone` is switched from –1 (default value, no selection) to a value between `0` wand `iPolygoneNb-1`.

B3.2 Rectangle and ellipse customzation

The procedure to customize a rectangle or an ellipse is very intuitive and similar to that described in the previous paragraph for the line object. However, remember that the object must be empty, i.e., free of agents and obstacles.

C Agent and Obstacle generation

C.1 Generation control box

Once an object has been created (line, rectangle, ellipse, etc … following the prescription described in the previous sections), it is possible to fill it up with agents and obstacles. This operation is controlled by the GENERATION box displayed in Fig. 36 page 113.

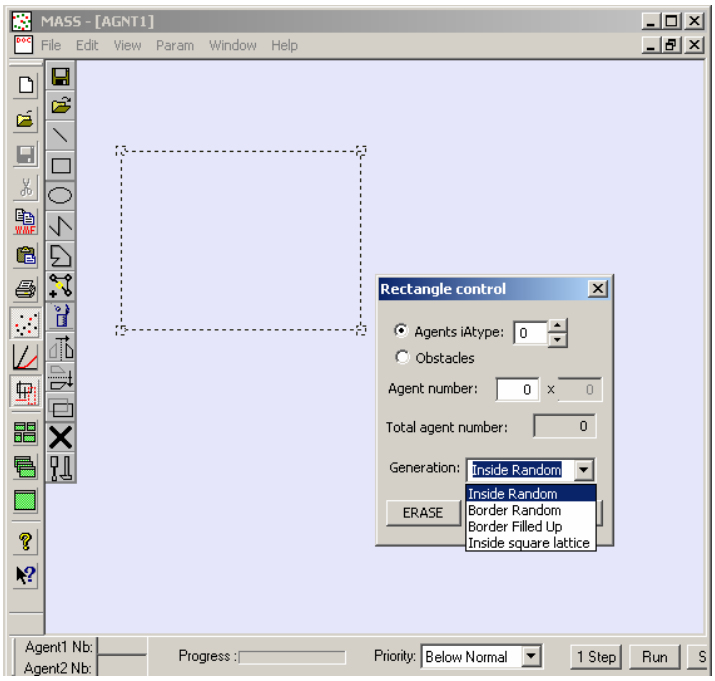


Fig. 36 : Generation control box

To fire this dialog box, simply **right click** the object. in Fig. 36, the user just right clicked the rectangle drawn in the screen. Firing the GENERATION box for the background is slightly more complicated: first, left click the background outside any object, keep the left button down and right click. In all cases, you should see the box represented in Fig. 36. Note that the left-top corner of the GENERATION box in the screen is exactly corresponds to the mouse position during the right-click action.This action triggers the function `CXDraft::OnRButtonDown` displayed below:

```
void CXDraft::OnRButtonDown(UINT nFlags, CPoint point)
//////////////////////////////////////////////////////////////////////////////
//////////////////////////////////////////////////////////////////////////////{
	CMainFrame* pMain= (CMainFrame*) AfxGetApp()->m_pMainWnd->GetTopLevelFrame();
	int i=0;
	//////////////////////////////////////////////////////////////////////////
	OnRButtonDownLineTest(nFlags,point);
	OnRButtonDownRectangleTest(nFlags,point);
	OnRButtonDownEllipseTest(nFlags,point);
	OnRButtonDownPolyLineTest(nFlags,point);
	OnRButtonDownPolygonTest(nFlags,point);
	if (IsLeftButtonDown) OnRButtonDownBackgroundTest(nFlags,point);
//////////////////////////////////////////////////////////////////////////////
	GetTotalObjectNb();
	//////////////////////////////////////////////////////////////////////////
	//UPDATE THE ARRAYS OF THE PROPERTY SHEET IF IT IS ALREADY OPEN
	if (pMain->m_pPropFrame != NULL) {
		pMain->m_pPropFrame->m_pModelessPropSheet->FullInitialize();
	}
	//////////////////////////////////////////////////////////////////////////
	CWnd::OnRButtonDown(nFlags, point);
}
```

The function `OnRButtonDown` launches for each graphical object in `CXDraft` the processing cycle shown in Fig. 37.

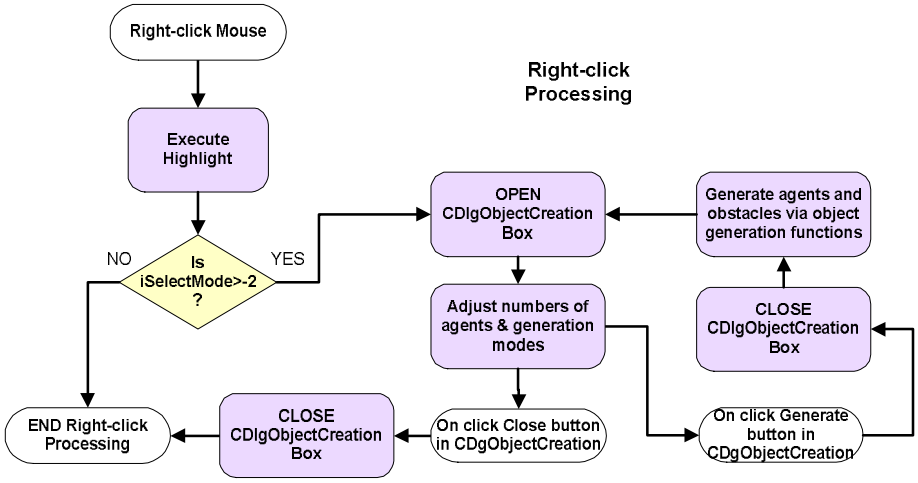


Fig. 37

This diagram simply shows that the cycle first tests whether some object has been selected by executing `HighLight` for all objects. If it is (see the flowchart of `Highlight` in Fig. 35 page 111)) `OBJ.iSelectMode`>-2, the cycle fires the dialog box (i.e., an instance Dlg of `CDgObjectCreation` class) to define the generation conditions of agents and (or) obstacles in the highlighted object. The header of this class is displayed below:

```
class CDlgObjectCreation : public CDialog
////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////
{
public:
	CDlgObjectCreation(CWnd* pParent = NULL);   // standard constructor
	virtual ~CDlgObjectCreation();
// Dialog Data
	enum { IDD = IDD_DLG_OBJ_GENERATION };
public:
	CPoint TopLeftCorner;
	int  m_iSelectedAType;         //SELECTED AGENT TYPE
	int  m_iAgentNb1[AGENTTYPENB];//
	int  m_iAgentNb2[AGENTTYPENB];//THIS SECOND NUMBER IS ONLY USED TO GENERATE
	                               //A SQUARE LATTICE OF AGENTS
	int  m_iGenMode[AGENTTYPENB];
	int  m_iSelectedAgentNb1;     //NB OF AGENTS OF TYPE m_iSelectedAType
	int  m_iSelectedAgentNb2;
	bool m_bAgentSelected;        //true IS THE AGENT MODE IS SELECTED
	int  m_iObstacleNb1;
	int  m_iObstacleNb2;  //THIS SECDOND NUMBER IS ONLY USED TO GENERATE
	                               //A SQUARE LATTICE OF OBSTACLES
	int  m_iObstacleGenMode;
	CComboBox InitGenMode;
	CNumSpinCtrl m_Spin1;
	HWND ParenthWnd;
	int iCallingObject;           //0: THIS FUNCTION IS CALLED BY A LINE
	                               //1: THIS FUNCTION IS CALLED BY A RECTANGLE
	                               //2: THIS FUNCTION IS CALLED BY AN ELLIPSE
	int  iCloseMode;              //iCloseMode=0 OK; iCloseMode=1  Test Generation
	                               //iCloseMode=2 Erase ALL
```

```
        int m_iTotalANb[AGENTTYPENB]; //TOTAL NB OF AGENTS CREATED IN ALL OBJECTS
        int m_iTotalObNb;             //TOTAL NB OF OBSTACLES CREATED IN ALL OBJECTS

        DECLARE_DYNAMIC(CDlgObjectCreation)

        afx_msg void OnSelChangeInitGenMode();
        afx_msg void OnPaint();
        afx_msg void OnBnClickedAgent();
        afx_msg void OnBnClickedObstacle();
        afx_msg void OnEnChangeAgentType();
        virtual BOOL OnInitDialog();
        afx_msg void OnBnClickedCheck1();
protected:
        virtual void OnOK();
        virtual void DoDataExchange(CDataExchange* pDX);    // DDX/DDV support
public:
        afx_msg void OnBnClickedCancel();
        afx_msg void OnBnClickedTestGeneration();
        afx_msg void OnBnClickedEraseObjects();
};
```

Fig. 38

The correspondence between the fields in the dialog box and the member variables of `CDlgObjectCreation` is as follows (see Fig. 38):

- "`Agents iAType`" updates `m_iSelectedAType`.
- The two edit controls located on the right side of the field "`Agent number`" define the number of agents. The right-most control is generally inactive, so that the number of agents is defined by the left sole active control. For instance in Fig. 38, the sole active edit control corresponds to `m_iAgentNb1[iAType]` and the program will set up `31=m_iAgentNb1[iAType]`. However, the right-most control may be activated, depending on the generation mode, in particular if the generation mode "`square lattice`" is selected. In that case, the program will set up `64=m_iAgentNb2[iAType]`. The total number of generated agents will be the product of the two numbers.
- The field "Total agent number" is not adjustable. It simply shows the total number of agents with the selected type `m_iSelectedAType` in all the created objects.
- The generation options available in the "Generation" combo box depend on the nature of the selected object. Generating agents and obstacles inside the object is possible for rectangles, ellipses and polygons. The rectangle object offers the most sophisticated generation options, comprising: `Inside random`, `Inside square lattice`, `Border random`, `Border filled up, square lattice` (see for instance Fig. 36 page 113).

This box controls the generation of agents and obstacles. To randomly generate 1000 agents of type=0 in the example represented in Fig. 36, change the "Agent number" field to 1000 and click the button "GENERATE". If you see no agents, check that the agent color is for instance different from the background! It is possible to generate objects inside the ellipse or on the border depending on the selection of the "generation" combo box. The generation mode depends on the nature of the selected object. The figure below show several examples of agents generation in various objects.

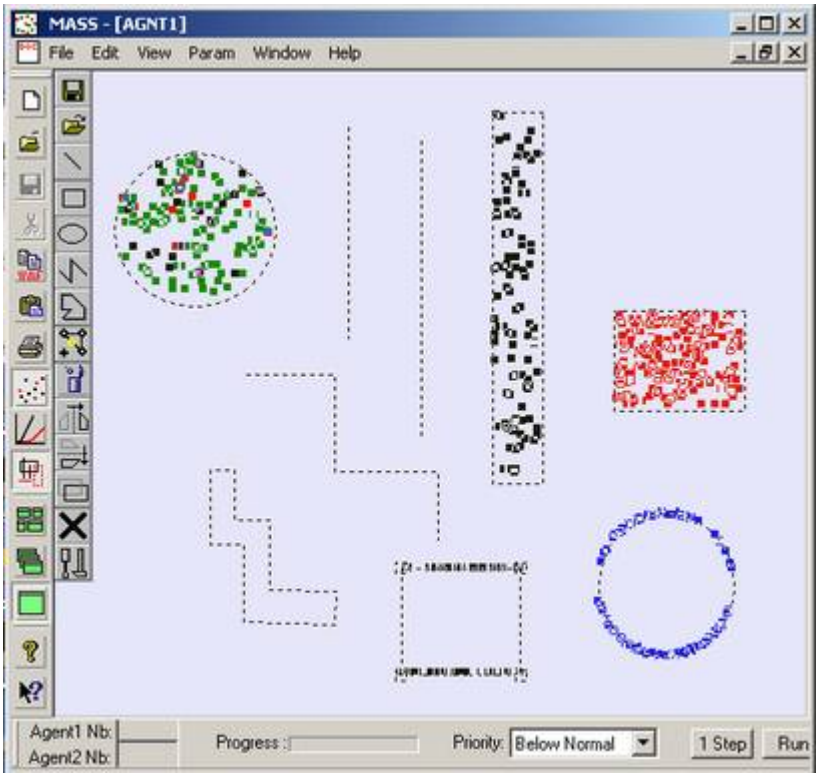


Fig. 39: Example of agent and obstacle distributions

It is important to describe the sequence of function calls following the click of the button GENERATE in the dialog box. The following functions are executed:

1. `void CDlgObjectCreation::OnBnClickedTestGeneration()`, which essentially stores the data of the edit boxes in the member variables of the class `CDlgObjectCreation`. The dialog box is closed with `iCloseMode=1`.
2. As the dialog box was a modal box, the control returns to the function which created the box. This function depends on the object, which was selected when right-clicking the draft windows. The control returns to:
   - `CXDraft::OnRButtonDownLineTest` if a line was selected.
   - `CXDraft:: OnRButtonDownRectangleTest` if a rectangle was selected.
   - `CXDraft:: OnRButtonDownEllipseTest` if an ellipse was selected.
   - `CXDraft:: OnRButtonDownPolylineTest` if a polyline was selected.
   - `CXDraft:: OnRButtonDownPolygonTest` if a polygon was selected.

   `CXDraft:: OnRButtonDownBacgroundTest` if the background was selected.

   Perhaps, the simplest method to understand the processing consists in studying in details a practical case. Let us assume that a rectangle was selected and populated with agents of obstacles. The function `OnRButtonDownRectangleTest` is executed. Its code is displayed below:

```
void CXDraft::OnRButtonDownRectangleTest(UINT nFlags, CPoint point)
//////////////////////////////////////////////////////////////////////////////////////////////
//////////////////////////////////////////////////////////////////////////////////////////////
```

```
{
     int i=0, j=0, k=0;
     ////////////////////////////////////////////////////////////////////////
     CAGNTView* pView=GetActiveView1();
     COLORREF AColor[AGENTTYPENB];
     for (k=0;k<AGENTTYPENB;k++) AColor[k]=pView->AgentColor[k][0];
     int XDim=pView->ThreadData.XDim;
     int YDim=pView->ThreadData.YDim;
     ////////////////////////////////////////////////////////////////////////
     RECT rect;
     GetParent()->GetClientRect(&rect);
     double XCoef=1.0/(rect.right-rect.left);
     double YCoef=1.0/(rect.bottom-rect.top);
     ////////////////////////////////////////////////////////////////////////
     CClientDC pDC(this);
     CPen* penCur = new CPen(this->iDefaultLineStyle,1,this->iDefaultDrawPen);
     pDC.SelectObject(penCur);
     pDC.SetROP2(R2_NOTXORPEN);
     ////////////////////////////////////////////////////////////////////////
     CDlgObjectCreation* dlg = new CDlgObjectCreation(this);
     iSelectedRect=-1;  //DEFAULT: NO RECTANGLE SELECTED
     for (i=0;i<iRectNb;i++) {
          m_Rect[i].HighLight(&pDC,rect,point,iDistMax);
          //REMEMBER THAT HighLight UPDATES iSelectMode TO -2,-1,0,1,2,3
          if (m_Rect[i].iSelectMode>-2) {
               iSelectedRect=i;
               bool bGenerate1=false;
               bool bGenerate2=false;
               while (!bGenerate1 || !bGenerate2) {
                    this->GetTotalObjectNb();
                    for (int k=0;k<AGENTTYPENB;k++) dlg->m_iTotalANb[k]=this->iAgentNb[k];
                    dlg->m_iTotalObNb=this->iObstacleNb;
                    for (j=0;j<AGENTTYPENB;j++) {
                         dlg->m_iAgentNb1[j]=m_Rect[i].iAgentNb1[j];
                         dlg->m_iAgentNb2[j]=m_Rect[i].iAgentNb2[j];
                         dlg->m_iGenMode[j]=m_Rect[i].iAgentGenMode[j];
                    }
                    dlg->TopLeftCorner=point;
                    dlg->m_iSelectedAType=m_Rect[i].iSelectedAType;
                    dlg->m_bAgentSelected=m_Rect[i].bAgentSelected;
                    if (dlg->m_bAgentSelected) {
                         dlg->m_iSelectedAgentNb1=dlg->m_iAgentNb1[dlg->m_iSelectedAType];
                         dlg->m_iSelectedAgentNb2=dlg->m_iAgentNb2[dlg->m_iSelectedAType];
                    }
                    else {
                         dlg->m_iSelectedAgentNb1=m_Rect[i].iObstacleNb1;
                         dlg->m_iSelectedAgentNb2=m_Rect[i].iObstacleNb2;
                    }
                    dlg->m_iObstacleNb1=m_Rect[i].iObstacleNb1;
                    dlg->m_iObstacleNb2=m_Rect[i].iObstacleNb2;
                    dlg->m_iObstacleGenMode=m_Rect[i].iObstacleGenMode;
                    dlg->iCallingObject=1;//THE DIALOG BOX IS CALLED BY A RECTANGLE
//LINE1               if (IDOK==dlg->DoModal()) {//
////////////////////////////////////////////////////////////////////////
//CRUCIAL: FIRST ERASE ALL EXISTING OBJECTS IN THE RECTANGLE!!!!!!!!!!
                    m_Rect[i].InvertInternalObjects(&pDC,rect,XDim,YDim,AColor);
////////////////////////////////////////////////////////////////////////
                    for (j=0;j<AGENTTYPENB;j++) {
                         m_Rect[i].iAgentNb1[j]=dlg->m_iAgentNb1[j];
                         m_Rect[i].iAgentNb2[j]=dlg->m_iAgentNb2[j];
                         m_Rect[i].iAgentGenMode[j]=dlg->m_iGenMode[j];
                    }
                    m_Rect[i].iSelectedAType=dlg->m_iSelectedAType;
                    m_Rect[i].bAgentSelected=dlg->m_bAgentSelected;
                    m_Rect[i].iObstacleNb1=dlg->m_iObstacleNb1;
                    m_Rect[i].iObstacleNb2=dlg->m_iObstacleNb2;
                    m_Rect[i].iObstacleGenMode=dlg->m_iObstacleGenMode;
                    ////////////////////////////////////////////////////////////////
//LINE2               if (dlg->iCloseMode==1) {//GENERATION OF AGENTS & OBSTACLES
```

```
                              //FIRST, DEFINE THE POPULATIONS OF AGENTS AND OBSTACLES
                              bGenerate1=m_Rect[i].FillInterior(XDim,YDim);
                              bGenerate2=m_Rect[i].FillBorder(XDim,YDim);
                              //SECOND, PAINT THE POPULATIONS IN THE TRANSPARENT WINDOW
                              if (bGenerate1 && bGenerate2)
                                   m_Rect[i].InvertInternalObjects(&pDC,rect,XDim,YDim,AColor);
                              bGenerate1=false;//TO FORCE REOPENING THE DIALOG BOX
                         }
                         ////////////////////////////////////////////////////////////
//LINE3                    else if (dlg->iCloseMode==2) {//DELETE ALL POPULATIONS
                              for (j=0;j<AGENTTYPENB;j++) {
                                   m_Rect[i].iAgentNb1[j]=0;
                                   dlg->m_iAgentNb1[j]=0;
                              }
                              dlg->m_iSelectedAgentNb1=0;
                              m_Rect[i].iObstacleNb1=0;
                              dlg->m_iObstacleNb1=0;
                              m_Rect[i].InvertInternalObjects(&pDC,rect,XDim,YDim,AColor);
                         }
                         ////////////////////////////////////////////////////////////
                    }
                    else {//CANCEL BUTTON
                         bGenerate1=true;
                         bGenerate2=true;
                    }
               }
          }
     }
     ////////////////////////////////////////////////////////////////////////
     pDC.SelectStockObject(BLACK_PEN);
     delete penCur;     //AS IT IS UNSAFE TO delete A SELECTED RESOURCE, THE BLACK_PEN
     delete dlg;
     ////////////////////////////////////////////////////////////////////////
}
```

The generation dialog box is open at LINE1. When it is closed with `iCloseMode=1`, the processing begins at LINE2. Note that the box is immediately reopened!

Several comments are in order here:

- Agents and obstacles generated in the background object are automatically created outside ellipses, rectangles and polygons.
- It is not possible to move a filled object, simply to avoid the overlap of agents or obstacles in different objects. To move an empty object, first erase the populations using the "ERASE all objects" button in the generation control box (see Fig. 36)
- Moving or resizing an empty object in a filled background may move background agents or obstacles inside the object. To avoid this issue, select the background and recalculate all populations.
- Note that Dlg does not directly create the agents. It is closed to come to the parent window to create to populations, and then reopened.

C.2 Serialization

Objects (i.e., lines, rectangles, ellipses…) are saved and read from disk files with the extension OBJ. Saving an object to disk consists in saving the object definition points, the number of generated agents and (or) obstacles, and the condition of generation. Note that the location of the agents or obstacles that contain each object are not saved. The conditions of generation (as defined in the generation combo) are only saved to disk.

The routine for saving to disk is `void CXDraft::OnFileSave()`, which calls `void CXDraft::WriteToDisk`.

The routine for read from disk is `void CXDraft::OnFileOpen()`, which calls `void CXDraft::ReadFromDisk`.

D Approximate distance to an ellipse

The ellipse equation reads: $\left(\frac{x-X_0}{A}\right)^2+\left(\frac{y-Y_0}{B}\right)^2=1$

The center of this ellipse is just the point (X_0,Y_0). Let us consider a point in (X,Y) in the plane. The equation of the line joining this point to the ellipse center is: $y-Y_0=\frac{Y-Y_0}{X-X_0}\left(x-X_0\right)$. The intersection of this line with the ellipse is represented by the 2 solutions of the following equation: $\left(\frac{x-X_0}{A}\right)^2+\left(\frac{Y-Y_0}{X-X_0}\right)^2\left(\frac{x-X_0}{B}\right)^2=1$

Thus: $x_\pm=X_0\pm\sqrt{\frac{1}{\frac{1}{A^2}+\left(\frac{Y-Y_0}{X-X_0}\right)^2\frac{1}{B^2}}}$, and $y_\pm=Y_0+\frac{Y-Y_0}{X-X_0}\left(x_\pm-X_0\right)$

The approximate distance to the ellipse is $D=Min\left(D_+,D_-\right)$ with $D_\pm=\sqrt{\left(X-x_\pm\right)^2+\left(Y-y_\pm\right)^2}$

Chapter 7

Interface: GDI & storage of simulation in WMF

The GDI module is a graphic module to trace the moves of the agents in the terrain.

The GDI module enables direct observation of the agent trajectories in the terrain as displayed in Fig. 40 and also saving the successive screen shots to disk. This functionality is indispensable in many cases, especially in inhomogeneous systems. It is possible to trace diffusion, to observe the emergence of order, or simply to debug the agent decision functions that can lead to inconsistent behaviors.

A Tracing agent moves

The simulation thread (Thread II, see Fig. 2 page 15) sends one WM_PAINT message to `CAGNTView` to update the display. Thus, the function `CAGNTView::OnPaint()` manages the representation of the data, with three possible display modes, i.e, the **Run Mode**, the **Chart Mode**, and the **Draft Mode** (see the Tutorial Manual). **Chart** and **Draft Modes** were described in chapters 5 and 6 respectively. The **Run Mode** shows the evolution of the agent population in the terrain. `CAGNTView::OnPaint()`directly calls the device-context functions to trace the moves of the agents through the terrain.

The member function `CAGNTView::OnUpdateDisplay` operates as a switch to update the display depending on the value of the parameter `iDisplayMode` with `iDisplayMode=0` for the Run Mode, `iDisplayMode=1` for the Chart Mode, `iDisplayMode=2` for the Draft Mode.

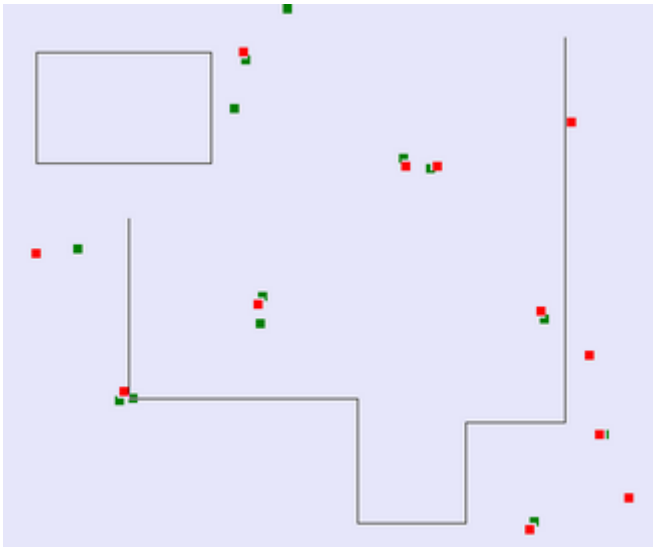


Fig. 40: Display of two populations of agents (red & green lines) and obstacles (black lines) by the module GDI in the Run Mode.

```
LRESULT CAGNTView::OnUpdateDisplay(WPARAM wparam,          //SCREEN SHOT INDEX
                                   LPARAM lparam)          //UNUSED
////////////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////////////
{
////////////////////////////////////////////////////////////////////////////////////////
       //MAKE SURE THAT NO ACTION CONCERNING THE INTERFACE IS CONCURENTLY IN PROGRESS
       CAGNTApp* pApp=(CAGNTApp*) AfxGetApp();
//     WaitForSingleObject(pApp->m_hSafe1,INFINITE);
////////////////////////////////////////////////////////////////////////////////////////
       CClientDC dc1(this);  //MANDATORY!!!!!!!!!!
       static int iPrevGraphMode =-1;
 ////////////////////////////////////////////////////////////////////////////////////////
       if (iDisplayMode==0) {//CURRENT DISPLAY: 2D REPRESENTATION OF AGENTS
              if (::IsWindowVisible(m_chart.m_hWnd)) m_chart.ShowWindow(SW_HIDE);
              if (::IsWindowVisible(m_draft.m_hWnd)) m_draft.ShowWindow(SW_HIDE);
              if (iDisplayMode!=iPrevGraphMode) {  //JUST TO ERASE THE BACKGROUND ONE TIME
                     PaintBackGround(&dc1,0);      //WHEN YOU SWITCH iGraphMode
                     iPrevGraphMode=iDisplayMode;
              }
              DrawObstacles(&dc1,0);
              DrawAgents(&dc1,1);
              DrawPolylines(&dc1,1);
       }
////////////////////////////////////////////////////////////////////////////////////////
       else if (iDisplayMode==1) {   //CURRENT DISPLAY: CHART MODE
              iPrevGraphMode=iDisplayMode;
              if (::IsWindowVisible(m_draft.m_hWnd)) m_draft.ShowWindow(SW_HIDE);
              if (::IsWindow(m_chart.m_hWnd)) m_chart.ShowWindow(SW_NORMAL);
              DrawChart(ThreadData.iShotIndex);//iScreen SAVED PREVIOUSLY IN GraphicUpdate
       }
////////////////////////////////////////////////////////////////////////////////////////
       else if (iDisplayMode==2) {   //CURRENT DISPLAY: DRAFT MODE
              if (iPrevGraphMode!=iDisplayMode) {
                     iPrevGraphMode=iDisplayMode;
```

```
                        if (::IsWindowVisible(m_chart.m_hWnd)) m_chart.ShowWindow(SW_HIDE);
                        if (::IsWindow(m_draft.m_hWnd)) {
                                m_draft.ShowWindow(SW_NORMAL);
                                m_draft.Invalidate();         //REDRAW THE DRAFT WINDOW
                        }
                }
        }
////////////////////////////////////////////////////////////////////////////////
        SetEvent(pApp->m_hSafe1);     //THUS ANY CALL TO WaitForSingleObjet(m_hSafe1)
////////////////////////////////////////////////////////////////////////////////
        return 0;
}
```

Note the calls to the member functions:

```
void CAGNTView::DrawAgents(CDC* dc, int iter)
void CAGNTView::DrawObstacles(CDC* dc, int iter)
```

to draw the agents and obstacles, including color and shape.

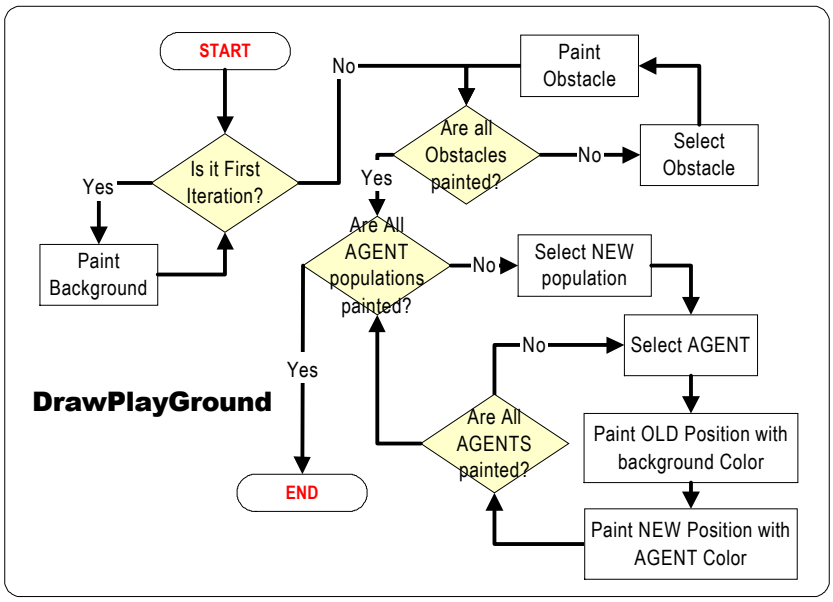


Fig. 41: DrawTerrain flowchart

B Saving the simulation shots to disk

Saving a simulation to disk consists in periodically storing WMF images of the terrain to a selected directory. This procedure is controlled by the Copy/Read property page displayed below in Fig. 42 page 123. To activate the simulation storage mechanim, click the check boxe entitled "Save to WMF files". This action launches the function `void CParamPage5::OnSetDirectory()`, which immediately fires the common dialog box to select a directory for the WMF files (see Fig. 42).

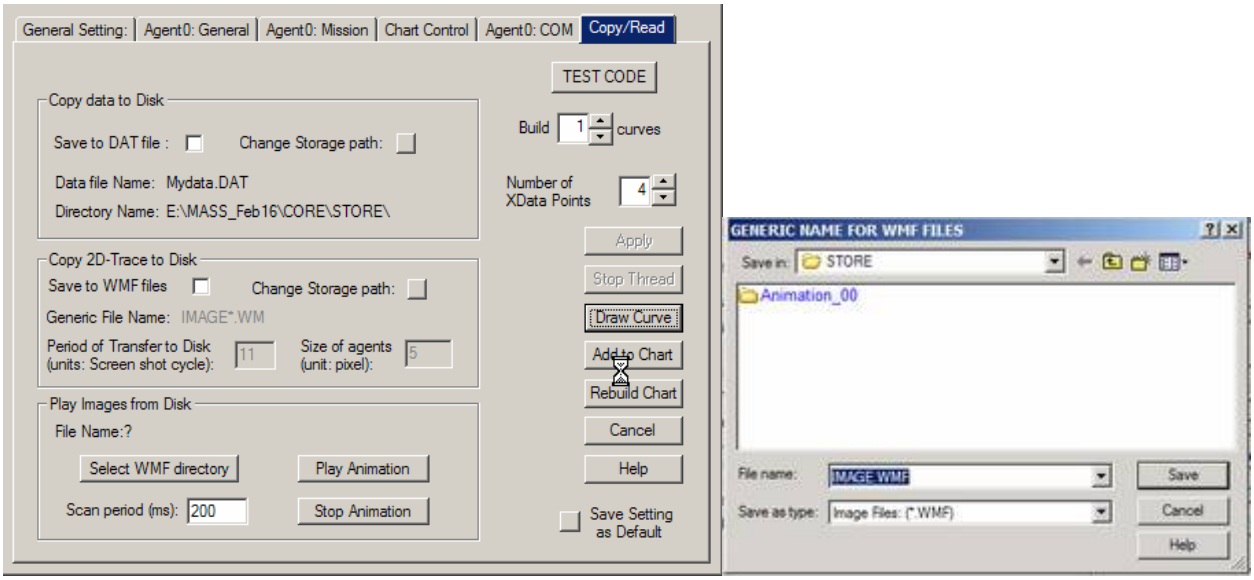


Fig. 42

The box entitled "GENERIC NAME FOR WMF FILES" enables selecting the directory to store WMF files. This name will be displayed in the field entitled "Generic File Name". In Fig. 42, WMF files will be named IMAGE0.WMF, IMAGE1.WMF, IMAGE2.WMF, etc...

The storage mechanism is executed at runtime by the simulation thread (Thread II, see Fig. 2 page 15). Explictly, the function `void MainTestAsynchronous(COREDATA* pData)` executes the next fragment of code to send the message `WM_SAVE_PLAYGROUND` to `CAGNTView` which ultimately executes `LRESULT CAGNTView::OnSavePlayground(..)` to save the playground each time it updates the screen to store the evolution.

```
////////////////////////////////////////////////////////////////////////////
//SECTION TO STORE THE PLAYGROUND DISPLAY TO DISK
if (pData->bSaveGroundToDisk) {
        int iterat= (int) (ScreenRefreshTime/ScreenShotPeriod);
        if ((iterat%pData->iTraceSavePeriod)==0)
                ::SendMessage(pData->m_ViewhWnd,WM_SAVE_PLAYGROUND,iterat,0);
}
////////////////////////////////////////////////////////////////////////////

LRESULT CAGNTView::OnSavePlayground(WPARAM wparam,          //ITERATION INDEX
                                    LPARAM lparam)          //UNUSED
//////////////////////////////////////////////////////////////////////////////////////
```

```
//FUNCTION TO SAVE AUTOMATICALLY THE PLAYGROUND TO A DISK FILE
////////////////////////////////////////////////////////////////////////////////
{
     CString FileName=ThreadData.TraceFileName; //GENERIC TraceFileName USER-DEFINED IN ParamPage5
     char buffer[20];
     _itoa( wparam, buffer, 10);
     if (wparam<10) FileName=FileName+"000"+buffer+".wmf";
     else if (wparam<100) FileName=FileName+"00"+buffer+".wmf";
     else if (wparam<1000) FileName=FileName+"0"+buffer+".wmf";
     else FileName=FileName+buffer+".wmf";
     CFile myFile(FileName,CFile::modeCreate | CFile::modeWrite | CFile::typeBinary);
     myFile.Close();
     CMetaFileDC * cDC = new CMetaFileDC();
     cDC->CreateEnhanced(GetDC(),NULL,NULL,"the_name");
     //NEXT CALL DRAWS THE METAFILE EXACTLY AS THE SCREEN
     DrawPlaygroundForDisk(cDC,0);          //SECOND PASSING PARAMETER UNUSED
     HENHMETAFILE handle = cDC->CloseEnhanced(); //CLOSE meta CMetafileDC AND GET ITS HANDLE
     if (CopyEnhMetaFile(handle,FileName.GetBuffer())==NULL)
                       MessageBox("ERROR TO COPY WMF TO DISK","",MB_OK);
     else DeleteEnhMetaFile(handle);
//   cDC->Detach();
     delete cDC;
     return 0;
}
```

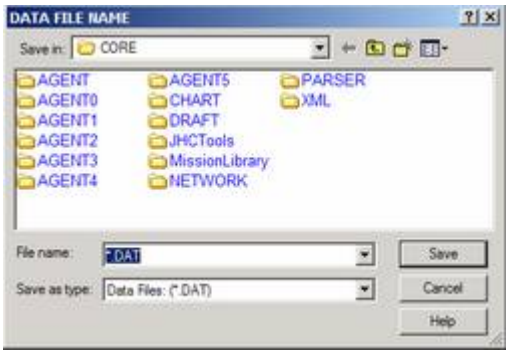
C Playing a simulation from disk

The simulation run has been saved in a directory as a series of WMF files. The reading of the different screen shots is controlled by the parampage represented in Fig. 42.

The reading is exectuted in a separate thread, to maintain the interaction with the interface. The Thread function is `UINT ThreadAnimProc(LPVOID pParam)`

D Saving data to disk

`void CParamPage5::OnBnClickedSaveDataTodisk()`, which calls the function `void CParamPage5::OnBnClickedDataDir()`.



The "DATA FILE NAME" box enables selecting the directory to store data, and the file name. These two names will be displayed in the field entitled "Data file Name" and Directory Name" of the Copy/Read property page,when closing the "DATA FILE NAME" box. In ????.

Chapter 8

Representation & Construction of the Environment

This chapter describes two representations of the agent environment (COARSE & FINE) and several constructions (Agent Scan, Cell Scan, Incremental, non Incremental, etc…).

Prior to developing any action, each agent must know how to represent its environment, and how to construct this representation. These preliminary steps are described in this chapter. Then, it can proceed its processing by identifying states and by following directives (i.e., high level actions) to apply a strategy (see chapter 2, page 33).

It is important to distinguish the environment representation mode from the environment construction mode.

- **The environment representation** is the way parameters are defined to represent the environment in the agent memory. The choice of the representation mode is a crucial step, which critically affects the way states and directives can be defined. The representation is often optimized with respect to some basic strategic ideas that will govern the agent directives. In the following, we consider two representation modes, designed as COARSE and FINE. The COARSE representation (see paragraph A.1 below, page 126) corresponds to the idea that an agent cannot observe far and close with the same accuracy. Thus, the far environment description is degraded compared to that deduced for close cells. The FINE representation (paragraph A.2 page 131) corresponds to the idea that there are no precision issues and that the agent can exactly know the position of the objects it detects inside its sense radius (agents & obstacles), independently of the distance.
- **The environment construction mode** is the way the environment is scanned. The construction mode is also important as it may critically affect the time needed to build the representation. In the following, we shall consider two construction modes (Cell Scan Mode or Agent Scan Mode). In the cell scan modes, the environment is constructed from the direct scan within a sense radius of the cells surrounding the agent. Real robots directly practice this method. In the agent scan modes, the environment is constructed

from the scan of computer memory. This method is not applicable to real agents except if we assume that a full-interconnected system is implemented through agent-agent communication. In general, it must be viewed as a method to shorten the simulation times at low agent density.

Note that, even if a representation has been chosen to implement easily some strategic principles, it has to be proven that the environment can be effectively constructed in a time compatible with the runtime constraints of the agent behavior or in a time that does not slow down too much the simulator performance. In practice, the faster the environment is calculated, the better!

The selection of the environment representation (COARSE or FINE) and the construction mode (Cell Scan mode, possible incremental, or AGENT Scan mode) is achieved in ParamPage2 (see Fig. 43). Note in particular the two group boxes entitled "`Environment Representation`" and `Environment Construction`".

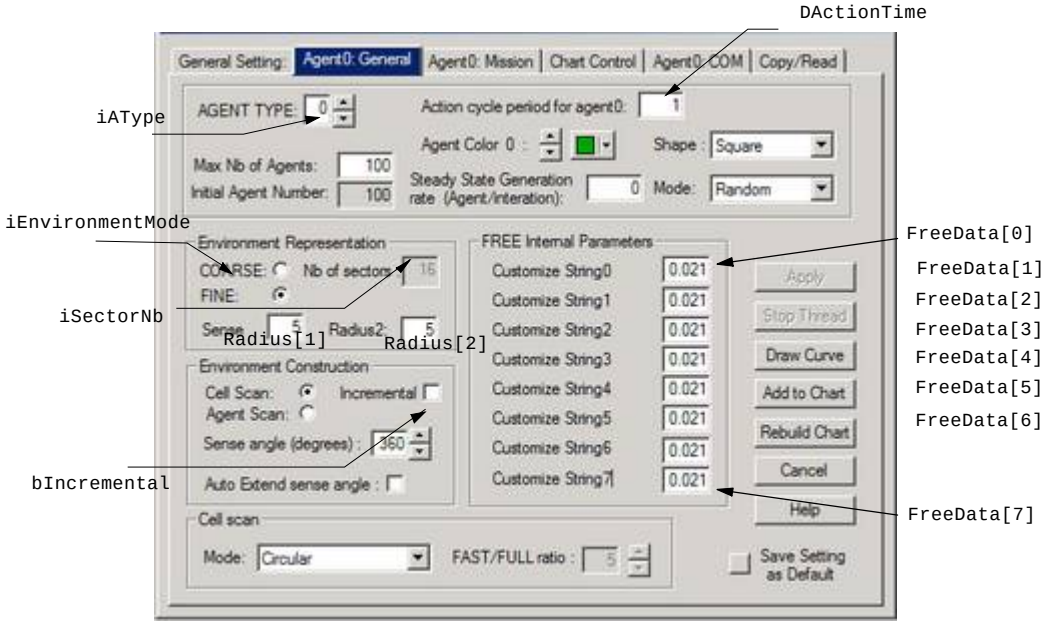


Fig. 43: Agent page for general settings (Representation mode, construction mode, initial distribution, steady state distribution)

A Environment representation

A.1 COARSE mode

A1.1 Definition

The COARSE mode corresponds to the idea that an agent observes far and close with different accuracies, and that the accuracy of the far-environment description is necessarily degraded *compared to that for close cells*.

In practice, we chose to distinguish as follows a nearby and a far environment. All zones are identified with polar-like coordinates (ρ,θ). A typical example of far representtation is shown in Fig. 44.

- **The nearby environment** is mapped with 25 elementary cells as represented in Fig. 44 (see the Class CELL definition page 20). We identify:
  - The zones ($\rho=0$, $0\leq\theta<7$), which represent the 8 cells adjacent to the agent in the red central square. These zones reduce to simple cells.
  - The zones ($\rho=1$, $0\leq\theta<15$), which correspond to the 16 cells one-cell farer from the agent.

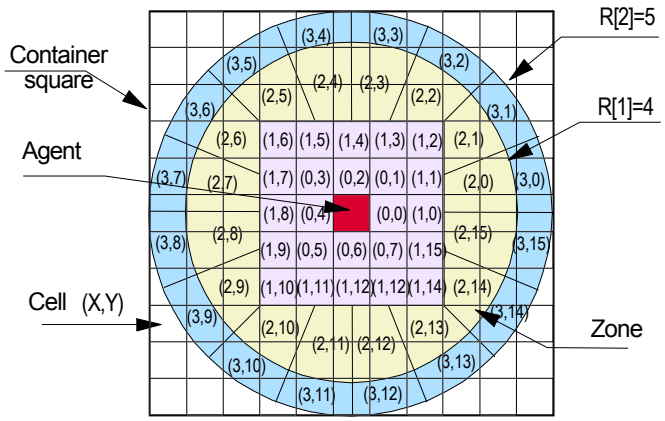


Fig. 44: Example of COARSE representation of the environment with 25 cells close to the agent and 16 angular sectors. The container cell comprises 120 cells, excluding the agent cell in the center.

- **The far environment** is described by angular sectors, with the restriction that the exact localization of the agents is impossible in these zones. The only available information is the number of objects (agents, obstacles) in each zone in accordance with the object ZONE definition page 22. Fig. 44 displays 16 angular sectors, but the number of sectors iSectorNb is customizable and user-defined. The zones ($\rho=2$, are inside a circle of radius R[1]=4, where "4" means 4 cells away from the agent located in the center. The zones ($\rho=3$, $0\leq\theta<15$), alse represent angular sectors. Again, The zones ($\rho=3$, are inside a circle of radius R[2]=5. 5 means 5 cells away from the agent located in the center.

For customization, the programmer may define a set of `iRadiusNb` radiuses. In Fig. 44, `iRadiusNb`=2. The total number of zones `NZ` necessary to buid the `COARSE` representtation is:

Eq. 3 `NZ=(2*R[0]+1)*(2*R[0]+1)-1+(iRadiusNb-1)*iSectorNb`

From Fig. 44, we deduce `iRadiusNb[0]=2.` So, `NZ=(2*2+1)*(2*2+1)-1+(3-1)*16=56`. One issue with the `COARSE` representation is that the far angular sector is composed of cells but some cells overlap with several angular zones as shown in Fig. 45. Thus, the zone-cell mapping is imperfect However, it is often not critical for the policy of the agent in (0,0), which does not need to know perfectly the location of far obstacles or far agents.

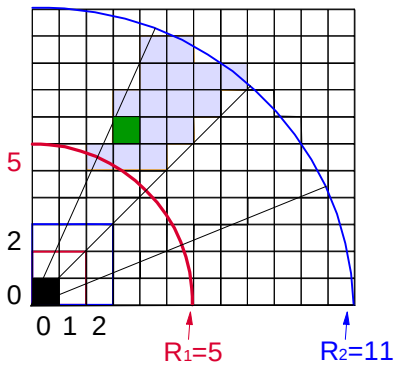


Fig. 45: Irregular decomposition of angular zones in elementary cells

A1.2 Array in memory

Logically, the environment is represented as an array of ZONE objects (see the ZONE definition in chapter 2, paragraph D.3 page 22). As for the terrain, we face the issue of storing a 2-index array (the indexes here are ρ & θ) in a 1-dimension table to enable dynamic adjustment of the zone number at runtime because the radius and the number of sectors are adjustable at runtime. The code to declare the array `Square1` reads :

```
short iLineLength=__max(16,iSectorNb);
short iZoneNb=(iRadius1Nb+1)*iLineLength;
ZONE* Zone = new ZONE[iZone1Nb];      //NEIGHBORHOOD SEEN BY AGENT 1
```

The number of zones necessary to define the representation is `NZ` (Eq. 3). This number comprises 8 zones for the first (square) neighborhood, 16 for the second (square) neighborhood, and `iSectorNb` zones per circular neighborhood. However, we chose to store `Square1` in an array with dimension `iZoneNb` slightly larger than `iZone1Nb`. The different zones are stored as follows:

- The 8 closest neighbors ($\rho=0, 0\leq\theta<7$) are stored in {`Zone[j] |0<=j<8`}.
- The 16 second closest neighbors ($\rho=1, 0\leq\theta<16$) are stored in the elements `Zone[iLineLength1+j]`|with 0<=j<16.
- The sectors ($\rho=2, 0\leq\theta<$iSector1Nb) are stored in the elements `Zone[2*iLineLength1+j]` with 0<=j<iSector1Nb.
- The sectors ($\rho=3, 0\leq\theta<$iSector1Nb) are stored in the elements {`Zone[3*iLineLength1+j]`} with 0<=j<iSector1Nb.
- And so on!

Clearly, this indexing sacrifices a few storage space especially if `iZoneNb>16`. In return, this storage mode is systematic as the `Zone[k]` stores the zone of coordinates (ρ=`k/iLineLength1`,θ= `k%iLineLength1`). The distance ρ to the agent is therefore easily accessed by the number `k/iLineLength1`.

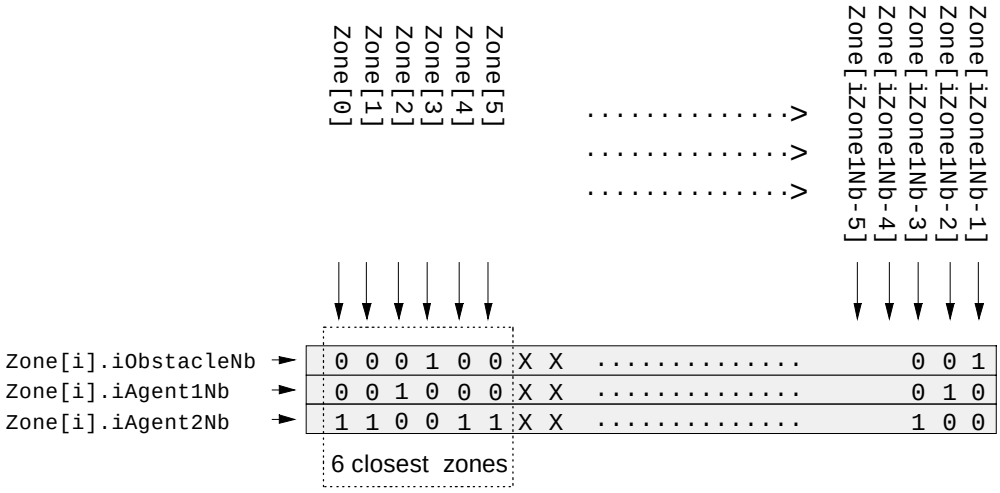


Fig. 46: Storage array of the states of the zones surrounding an agent

A1.3 Class COARSE_ENVIRONMENT

In the COARSE representation, one must determine the number of agents and obstacles in each zone {Square[k]|0<=k<iZone1Nb} of polar coordinates (ρ=k/iLineLength1, θ=k %iLineLength1). The way the environment representation is built is the problem of the environment construction.

Independently of the construction method, this array needlessly stores empty zones, i.e., zones without obstacles or agents. Therefore, it wastes a fraction of the memory that may become a critical handicap when considering very large populations of agents. Thus, we build the class COARSE_REPRESENTATION, which contains the adjustable array of filled zones, the size of which is adjusted at run time to the number of zones really filled in the array {Square1[k]|0<=k<iZone1Nb}. The declaration is as follows:

```
class COARSE_ENVIRONMENT
////////////////////////////////////////////////////////////////////////////
//  THE ENVIRONMENT STATE IS DESCRIBED BY A SET OF iFilledZoneNb ZONES THAT CONTAINS
//  AGENTS OF OBSTACLES. THE NUMBER iFilledZoneNb IS COMPUTED AT RUN TIME, AT EACH
//  ITERATION.
////////////////////////////////////////////////////////////////////////////
{
    public:
        COARSE_ENVIRONMENT();
        void Build(short YDim);
        void ReBuild(short YDim);
        ~COARSE_ENVIRONMENT();
        short  iFilledZoneNb;   //NB OF ZONES WHICH ARE NOT EMPTY; DIMENSION OF Zone
        ZONE*  Zone;            //
        short  iCStateIndex;   //THE CRITICAL STATE ASSOCIATED TO THE PHYSICAL STATE
};
```

A.2 FINE mode

A2.1 Definition

The FINE mode corresponds to the idea that there are no precision issues and that the agent can exactly know the position of the objects it detects within a sense radius. Contrarily to the COARSE representation, it is not necessary to define far angular sectors. The agent stores in its memory the series of agents and obstacles it detects within its sense radius.

A2.2 Array in memory

The agent header (see paragraph D.6, page 23) includes the following lines, which show that each agent stores the FINE representation of its environment in three respectively entitled `FoundAgent`, `FoundObstacle` and `FoundNode`:

```
////////////////////////////////////////////////////////////////////////////////
      //SECTION 3 : ENVIRONMENT STATES: FINE MODE
      //READ THE PROGRAMMER'S MANUAL FOR INFORMATION
      short (*FoundAgent[AGENTTYPENB][ITERATNB])[COMPONENTNB];
      short iDimA[AGENTTYPENB][ITERATNB];
      short iFoundANb[AGENTTYPENB][ITERATNB];
      short (*FoundObstacle[ITERATNB])[COMPONENTNB];//
      short iDimOb[ITERATNB];         //
      short iFoundObstNb[ITERATNB];   //NB OF FOUND OBSTACLES STORED IN FoundObstacle
      short (*COPY)[COMPONENTNB];     //COPY POINTER FOR TEMPORARY STORAGE
      short DimCOPY;                                  //
////////////////////////////////////////////////////////////////////////////////
//ARRAY TO CHARACTERIZE THE NODES FOUND BY THE AGENT.
//NOTE THAT NODES ARE AGENTS FOUND INSIDE THE COMMUNICATION RADIUS. THUS, THIS ARRAY IS
//LARGER THAT THE ARRAY FoundAgent, WHICH CORRESPONDS TO DIRECT SENSING OF THE ENVIRON
//MENT
      short (*FoundNode[AGENTTYPENB][ITERATNB])[COMPONENTNB2];
      short iDimNode[AGENTTYPENB][ITERATNB];
      short iFoundNodeNb[AGENTTYPENB][ITERATNB];
        ////////////////////////////////////////////////////////////////////////////////
```

FoundAgent

The first line of the header declares the 4-index array `FoundAgent[i][j][k][q]` where:

- The first index `0<=i<AGENTTYPENB` is the type of the found agent. For instance, data regarding the found agents `iAtype=1` are stored in `FoundAgent[1][j][k][q]`.
- The second index `0<=j<ITERATNB` is the iteration index. For instance, data regarding the found agents `iAtype=1` collected during the current iteration are stored in `FoundAgent[1][0][k][q]`. Data collected in the previous iteration are stored in `FoundAgent[1][1][k][q]`, and so on…
- The third index `k` is the discovery rank (i.e., the index) of the agent. For instance, Data regarding the first found agent of `iAtype=1` during the current cycle are stored in `FoundAgent[1][0][0][q]`. Data regarding the second found agent of `iAtype=1` are stored in `FoundAgent[1][0][1][q]`.

A crucial point results from the declaration of the 4 index array as:

```
short (*FoundAgent[AGENTTYPENB][ITERATNB])[COMPONENTNB]
```

The array is considered by the compiler as a 2-index table of pointers to vectors with `COMPONENTNB` components! In other words, `FoundAgent[i][j]` is a pointer to an array of dimension `iDimA[i][j]` of vectors with `COMPONENTNB` components (used to store the information

found by the agents of type i at iteration j). From this declaration, it results that the dimension of k in FoundAgent[i][j][k][q] is adjusted at runtime and to represent the maximum number of found agents of type-i. The FoundAgent arrays are typically initialized with the following code (see the function void AGENT::Build):

```
for (k=0;k<ITERATNB;k++) for (int q=0;q<AGENTTYPENB;q++)
{
       iDimA[q][k]=INITIAL;//MAX NUMBER OF FOUND AGENTS (INITIALIZATION)
       iFoundANb[q][k]=0;      //NB OF FOUND AGENT STORED IN FoundAgent[q][k]
       FoundAgent[q][k] = new short [INITIAL][COMPONENTNB];
}
```

Note that the dimension of the index k must be adjusted at runtime when the number of detected agent becomes larger than INITIAL.

- Finally, the last index q in the array FoundAgent[i][j][k][q] (0≤q<COMPONENTNB) enables to identify agent data. The following identification holds (latest revision: Oct 15, 2002):
  - FoundAgent[i][j][k][0]: **Absolute** X-coordinate of the cell containing the found agent
  - FoundAgent[i][j][k][1]: **Absolute** Y-coordinate of the cell containing the found agent
  - FoundAgent[i][j][k][2]: teta=arctg(Y/X), i.e, direction to move from the agent to the found agent. This direction is measured in multiples of π/4, thus, it is an integer such that: 0≤teta<8.
  - FoundAgent[i][j][k][3]: Target flag. Possible values:
    0: undefined;
    1: the agent iAtype = j has been identified as a target by the policy, which is developed in conjunction with the environment construction. This flag is useful in the non-incremental mode for the following reason. In that mode, the agent scans its entire environment (until the sense radius) and therefore, may store the localization of several preys, some ones that can be attacked and some other ones that cannot be attacked in accordance with the policy under consideration. In a second step (in the non-incremental mode) the agent scans the preys it detected (in the function FINECellFindState) and uses FoundAgent[i][j][k][3] to choose one prey.
    2: The agent has identified a predator.
  - FoundAgent[i][j][k][4]: iRank of the found agent in the Agent[i] array.

Note some redundancy due to the above definition of the array FoundAgent[i][j][k][. For instance, the following identity holds:

X=FoundAgent[0][0][0][0]=Agent[0][FoundAgent[0][0][0][4]].X

FoundObstacle

The 3-index array FoundObstacle[i][j][k] stores the obstacles found by the agent.

- The first index 0<=j<ITERATNB is the iteration index. For instance, all information regarding the obstacles collected during the current iteration is stored in FoundAgent[0][k][q]. Information collected in the previous iteration is stored in FoundAgent[1][1][k][q], and so on.
- The second index k is the rank (i.e., the index) of the obstacle. It simply identifies the obstacle. For instance, all information regarding the the first found obstacles is stored in FoundObstacle[0][0][q].
- Finally, the components {FoundAgent[i][j][k][q] |0≤q<COMPONENTNB)} have the following meaning (latest revision: Oct 15, 2002):

- `FoundObstacle[i][j][0]`: **Absolute** X-coordinate of the cell containing the found obstacle
- `FoundObstacle[i][j][1]`: **Absolute** Y-coordinate of the cell containing the found obstacle

FoundNode

The agent stores in the 4-index array `FoundNode[i][j][k][q]` the information it retrieves on the other nodes during the scan of its environment. This array is organized as the array FoundAgent[i][j][k][q] with the following differences regarding the interpretation of the last index (`0≤q<COMPONENTNB2`):

- `FoundNode[i][j][k][0]`: X-coordinate of the cell containing the agent.
- `FoundNode[i][j][k][1]`: Y-coordinate of the cell containing the agent
- `FoundNode[i][j][k][2]`: Open, undefined.

A2.3 Storage procedures

To store an obstacle or an agent, call the member function:

```
void AGENT::FINEStoreInArray(short iType,  //-1,0,1 FOR OBSTACLES,AGENT[0],AGENT[1]..
                             short iCell,  //ABSOLUTE X COORDINATE OF THE FOUND AGENT
                             short jCell,  //ABSOLUTE Y COORDINATE OF THE FOUND AGENT
                             short Index,  //READ THE EXPLANATION BELOW
                             bool  bXtorus,
                             bool  bYtorus,
                             short XDim,
                             short YDim)
```

Call this function with `iType=-1` to store an obstacle in the array `FoundObstacle`. Otherwise, call it will `0≤iType<AGENTTYPENB` to store an agent in the array `FoundAgent`. Note that this function includes several protection mechanisms, which makes that:

- An obstacle or an agent cannot be stored two times in the arrays.
- The agent, which executes `FINEStoreInArray` cannot self-detect itself and store itself in the memory.

B Environment construction: Cell scan, FINE representation

In all Cell Scan Modes (CSM), the agent analyzes the surrounding cells within the sense radius. There are several CSMs, depending on the way the agent scans surrounded cells. They critically affect the simulation speed. As will be shown below, one solution for fast environment scan consists in keeping track and in using the position of the agents and obstacles stored in the previous scans to limit the number of analyzed cells. However, there is a trade-off between environment scan speed and safety of identification.

It is important to stress that scan functions are located in each DLL. **Thus, some CORE facilities are executed by function located in each DLL**. The DLL programmer can modify the scan conditions, although in principles he has not to customize the CORE facilities.

B.1 Scan modes in the ACTION cycle

HISTORY OF SECTIONS B.1-B.4: Version 1.0: Feb 2004: A. Deheurles
Version 2.0: May 2006: JHC

Recall that the CORE scheduler activates each agent in the `ACTION` or in the `NODE` cycle. The `NODE` cycle is only executed for communicating agents. In the `ACTION` cycle, the agent is free to scan or to not scan (depending on its policy) its environment to identify the agents and the obstacles inside its sense disk.

Scan modes in the ACTION cycle are managed by the agent method `AGENT::ScanFINECellAction`, which is a DLL entry function directly called by the CORE to scan the environment cells. Each DLL has a private copy of this function that can be customized if necessary. The code of the function `AGENT::ScanFINECellAction` is displayed below for clarity.

The environment construction mode is selected by the box "Environment construction displayed in Fig. 43 page 127. There are two basic, scan functions, namely:

`ScanFINECellMode1`: This function scans the cells inside the sense disk around the agent in a circular mode, with a sense agnel of 360°, starting from the closest cell. It stores in the private memory of the agent the coordinates of the cells containing the discovered agents or obstacles.

`ScanFINECellMode2`: This function scans the cells inside the sense disk as follows:

1)It scans the 24 cells of the close environment.

2)It scans the close environment around the agents found at the preceding scan and stored in the private memory of the agent

3)In the non-incremental mode, it scans the sense disk close to the max radius, to detect the possible penetration of agents in the sense disk

Four scan modes are defined from these two functions . The scan may be:

- **Circular**: It is the default mode. The agent exclusively uses the function `ScanFINECellMode1` to scan the cells inside its sense disk. Thus, the circular mode scans each cell one time in the sense (or the communication) disk.

  This mode is displayed in Fig. 47 below. Simply, the agent first analyses the occupation of the cells in the close 5x5 squares in the center( ). Then, it analyses the cells associated with the purple color , then the cells with the pink color , and so on through the colors represented in the next squares , , , , , to approach a circular environment at large distance. This way, the agent scans its environment in the ascending order of distance to cells.

  When a cell contains an agent, it is automatically stored in the agent memory, i.e. in the array `AGENT::FoundAgent[i][j][k][m]`(see the description of the agent memory). Similarly, if the cell contains an obstacle, it is stored in the array `AGENT::FoundObstacle[j][k][m]`.

- **Circular & around agents**: The code alternates the functions `ScanFINECellMode1` and `ScanFINECellMode2`. The edit box `FAST/FULL scan ratio`" adjusts the relative frequency of the two modes. For instance, in Fig. 53, the ratio is 5, meaning that one Circular mode is executed every 5 scans. Setting the ratio to 1 would mean that the agent only uses the circular mode!

```
//     INFORMATION:
//  THIS ROUTINE BUILDS THE REPRESENTATION OF THE ENVIRONMENT BY SCANNING THE SENSE
//  DISK AROUND THE AGENT AS FOLLOWS:
//  1) IT FIRST SCANS THE 24 CELLS OF THE CLOSE ENVIRONMENT AROUND THE AGENT.
```

```
//     1) IT SCAN THE CLOSE ENVIRONMENT AROUND THE AGENT POSITIONS FOUND AT THE
PREVIOUS
//      SCAN & PREVIOULSY STORED IN THE ARRAY FoundAgent.
//     2) IN THE NON-INCREMENTAL MODE, SCAN THE AGENT SENSE DISK CLOSE TO THE MAX
RADIUS TO
   //      TO DECTECT EXTERNAL AGENTS ENTERING THE SENSE RADIUS.
```

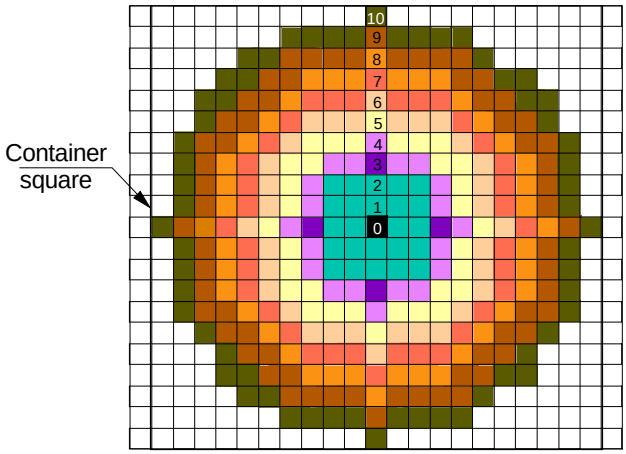


Fig. 47**:** Incremental construction of the environment in the ring mode. The different colors show the cell which are added every iteration, until iteration 10.

- **Automatic**: Here, the agent calculates the number of cells, which it would have to scan calling `ScanFINECellMode1` or `ScanFINECellMode2`, and it chooses the method that scans the smaller number of cells. The Circular method is general more efficient at high agent density, i.e., when there is much agent in the communication circle.
- **Free for test**: This methods calls `ScanFINECellMode2` only.
- **Rectangular**: This mode is obsolete. However, the code still includes several functions to scan the environment following the rectangular construction shown in **Fig. 48**.

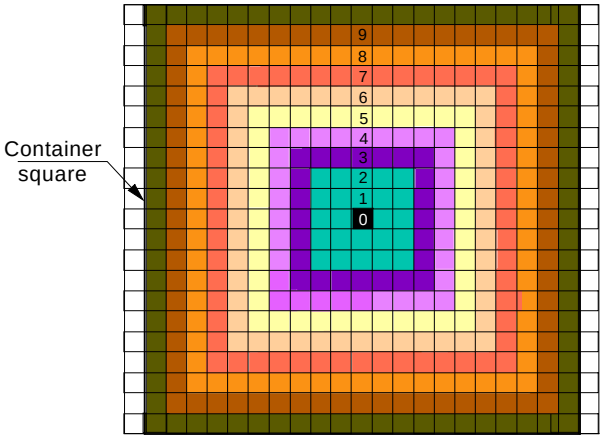


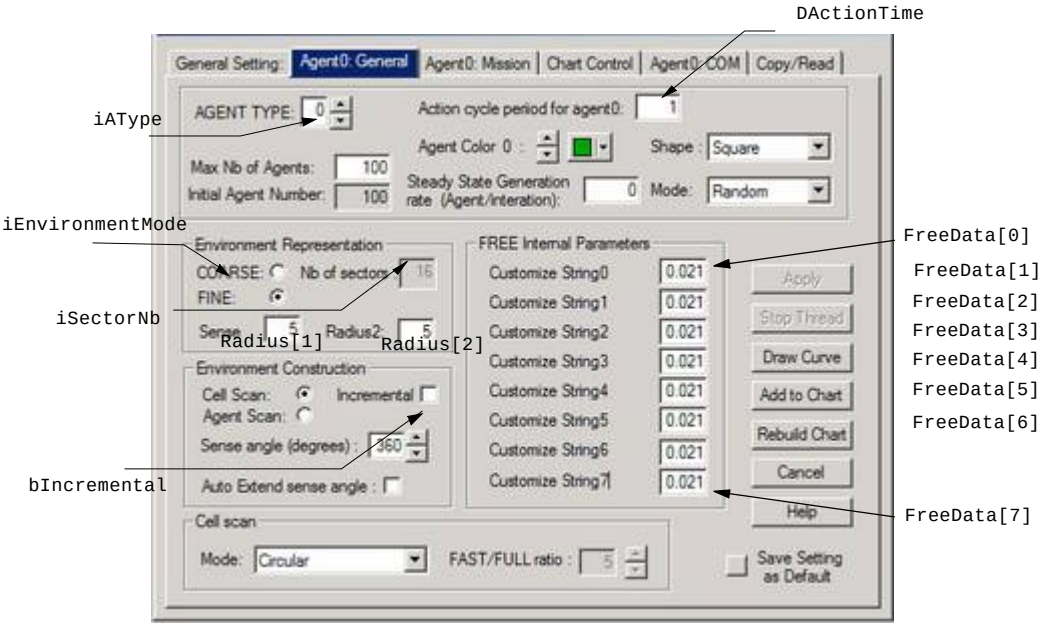
Fig. 48: Incremental construction of the environment in the rectangular mode. The different colors show the cell which are added every iteration, until iteration 10.

It is important to stress that this function is always call with this limit for the spatial extension of the scan:

```
MinRadius=ThreadData.Radius[i][0]= 2;
```

MaxRadius=ThreadData.Radius[i][1]=pApp>GetProfileInt(Str,"Radius1",5);

Thus, it results that in the FINE mode, Radius[0] and Radius[1] are exclusively used. Consequently, the edit box for Radius[2] is UNUSED when the FINE mode is selected (see figure below).




```
__declspec(dllexport)
        void  AGENT::ScanFINECellAction(CELL* Cell,short XDim,short YDim,
                                AGENT*  Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                                OBSTACLE* Obstacle, short iObstacleNb,
                                bool bXTorus, bool bYTorus,
                                short MaxRadius, short MinRadius)
////////////////////////////////////////////////////////////////////////////////
//      HISTORY: VERSION 1.0: Aymeric Deheurles, dec. 2003
////////////////////////////////////////////////////////////////////////////////
{
    switch (iScanTypeA) {
        case 0: //SCAN TYPE = 0
            ScanFINECellMode1(Cell,XDim,YDim,Agent,iAgentNb,
                              Obstacle, iObstacleNb, bXTorus, bYTorus,
                              MaxRadius, MinRadius, 0);  //0 FOR ACTION CYCLE
            break;
        case 1: //SCAN TYPE = 1
            if (iACTIONFastFullNb%iFastToFullScanRatioA == 0)
                ScanFINECellMode1(Cell,XDim,YDim,Agent,iAgentNb,
                                  Obstacle, iObstacleNb, bXTorus, bYTorus,
                                  MaxRadius, MinRadius, 0); //0 FOR ACTION CYCLE
            else {
                ScanFINECellMode2(Cell,XDim,YDim,Agent,iAgentNb,
                                  Obstacle, iObstacleNb, bXTorus, bYTorus,
                                  MaxRadius, MinRadius, 0);//0 FOR ACTION CYCLE
            }
            break;
        case 2: //SCAN TYPE = 2: ADAPTATIVE SCAN
            if (iACTIONFastFullNb%iFastToFullScanRatioA == 0)
                ScanFINECellMode1(Cell,XDim,YDim,Agent,iAgentNb,
                                  Obstacle, iObstacleNb, bXTorus, bYTorus,
```

```
                                MaxRadius, MinRadius, 0);//0 FOR ACTION CYCLE
            else {
                int Somme=0;
                int Dist=3;
                //FullArea = NUMBER OF CASES SCANNED BY FULL METHOD
                double FullArea=PI*MaxRadius*MaxRadius;
                //LightArea = AREA SCANNED BY DllFINECellScanMode2
                double LightArea=0;
                //Sum = NUMBER OF DIFFERENT TYPE AGENTS FOUND AT LAST ITERATION
                for (int i=0;i<AGENTTYPENB;i++) Somme+=iFoundANb[i][1];
                //Area = CIRCUMFERENCE SCANNED BY DllFINECellScanMode2 WITH RingScan
                for (int j=MaxRadius-Dist;j<=MaxRadius;j++) LightArea+=2*PI*j;
                //Area IS THE SUM OF CIRCUMFERENCES AND CLOSE CASES (24) AROUND EACH AGENT
                LightArea=LightArea+24*(Somme+1);
                //TEST WHICH IS THE LESS-CONTRAIGNANT METHOD
                if (FullArea < LightArea)
                    ScanFINECellMode1(Cell,XDim,YDim,Agent,iAgentNb,
                                      Obstacle, iObstacleNb, bXTorus, bYTorus,
                                      MaxRadius, MinRadius, 0);
                else ScanFINECellMode2(Cell,XDim,YDim,Agent,iAgentNb,
                                       Obstacle, iObstacleNb, bXTorus, bYTorus,
                                       MaxRadius, MinRadius, 0);//0 FOR ACTION CYCLE
            }
            break;
        case 3: //SCAN TYPE = 3
            ScanFINECellMode2(Cell,XDim,YDim,Agent,iAgentNb,
                              Obstacle, iObstacleNb, bXTorus, bYTorus,
                              MaxRadius, MinRadius, 0);//0 FOR ACTION CYCLE
            break;
    }
}
```

The function calls in the ACTION mode are displayed below:

```
__declspec(dllexport) void AGENT::ScanFINECellAction
          void AGENT::ScanFINECellMode1
               bool AGENT::ScanFINECellClose
                    #include "CellProcAction.cpp"
               bool AGENT::ScanFINECellRing
                    #include "CellProcAction.cpp"
               bool AGENT::ScanFINECellSector
                    #include "CellProcAction.cpp"
           void AGENT::ScanFINECellMode2
               bool AGENT::ScanFINECellClose
                    #include "CellProcAction.cpp"
               bool AGENT::ScanFINECellAroundObjects
                    #include "CellProcAction.cpp"
               bool AGENT::ScanFINECellAroundObjectsSector
                    #include "CellProcAction.cpp"
               bool AGENT::ScanFINECellRing
                    #include "CellProcAction.cpp"
```

The indentation displays the calls. For instance, `ScanFINECellAction` calls `ScanFINECellMode1` or `ScanFINECellMode2`, which calls the "low-level" functions `ScanFINECellClose`, `ScanFineCellRing`, `ScanFINECellSector`… and so on. All low-level functions call the same behavioral blocks `CellProcAction.cpp`. The benefice of this approach is that the code, which scans the environment, is decoupled from the code, which analyzes each cell to define the agent behavior! Why? It is very important to understand the following point:

In the `ACTION` cycle, the agent is free to scan or to not scan (depending on its policy) its environment to identify the agents and the obstacles inside its sense disk.

- In the NON-INCREMENTAL scan mode (selected by a check box in the interface), The agent completely scans the cells in the sense disk. The agent behavior (i.e., the recognition of states) is implemented in the sole function `ScanFineDecisionTree`.
- In the INCREMENTAL scan mode, the agent can stop at any time the scan process. The agent behavior is implemented in the block `CellProcAction.cpp` and in the function `ScanFineDecisionTree`. **The agent stops its construction in the block `CellProcAction.cpp`**.

B.2 Low-level scan functions

We describe in details in this section the low-level scan functions, namely `ScanFINECellRing`, `ScanFINECellSector`, `ScanFINECellAroundObjects`, `ScanFINECellAround-ObjectsSector`, and `ScanFINECellClose`

B2.1 ScanFINECellRing

```
bool AGENT::ScanFINECellRing(CELL* Cell, short XDim, short YDim,
                             AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                             OBSTACLE* Obstacle, short iObstacleNb, short iDistInit,
                             bool bXtorus, bool bYtorus, short XPos, short YPos, int iMode)
```

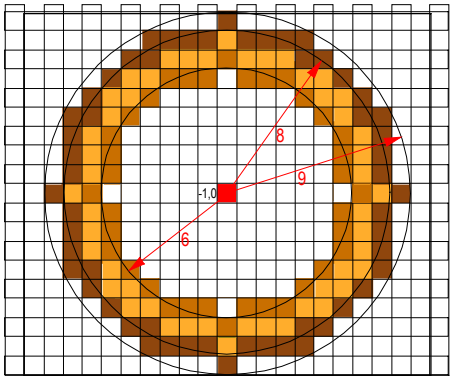


Fig. 49: The light-blue, dark green and light green cells show the cells scanned by the function `ScanFINECellRing` respectively called with `iDinstInit`=7, 8 or 9.

This function scans all cells approximately located in a thin ring around a center of absolute coordinates (`XPos`,`YPos`) as show in Fig. 49. The distance to the center is d such that `iDistInit`<d≤`iDistInit`+1.

It must be stressed that the function alternatively scans the ring cells from left to right or from right to left (and similarly up or down) to maintain the isotropy of the scan mechanism.

The function calls `CELLProcAction.cpp` for each cell in the ring if `iMode=0` (`ACTION` mode), and `CELLProcNode.cpp` if `iMode=1` (`NODE` mode).

B2.2 ScanFINECellSector

```
bool AGENT::ScanFINECellSector(CELL* Cell, short XDim, short YDim,
                               AGENT* Agent[AGENTTYPENB],   short iAgentNb[AGENTTYPENB],
                               OBSTACLE* Obstacle, short iObstacleNb,
                               short iDistInit, bool bXtorus, bool bYtorus,
                               short XPos, short YPos, int iMode,
                               double Teta1, double Teta2) //WARNING: ANGLES IN DEGRES
```

This function is used to scan the cells approximately located in a thin ring around a center of absolute coordinates (`XPos`,`YPos`) and additionally symmetrically located on the two symmetric angular sectors along the move direction of the agent (i.e., the variable `AGENT::iSect[1]`).

For simplicity and clarity, let us consider an example, i.e., the call of `ScanFINECellSector` with `iDistInit=9`. `ScanFINECellSector` considers the cells defined previously with `ScanFineCellRing` (see Fig. 49). Now let us consider that the agent moves east, parallel to the X axe. In that case, `ScanFINECellSector` scans the cells in the two angles *A0B* and *A'0B'* (see Fig. 50a). *C0A* and *C0B* are respectively the call parameters `Teta1` and `Teta2`. Concretely, these cells of coordinates (x,y) are identified by the conditions:

Eq. 4 $x1=iDisInit.\cos(COA=\mathbf{Teta1}) < x \leq x2=iDisInit.\cos(COB=\mathbf{Teta2})$

Eq. 5 $iDistInit^2 < x^2 + y^2 \leq (iDistInit+1)^2$

Fig. 50b shows the sectors scaned when the agent moves Northeast. Again, the function `ScanFINECellSector` scans the cells in the two angles *A0B* and *A'0B'*. Now, these angles are nothing but the angles *A0B* and *A'0B'* in Fig. 50a rotated with an angle θ. Thus, the solution consists in scanning the cells in the angles represented in Fig. 50a, and in checking the occupation of the real cells in Fig. 50b using a rotation of angle θ. In other words, the cells are scanned using Eq. 4 and Eq. 5, and the occupation is tested for the rotated cell (x',y') defined using the rotation equations:

$$x' = x \sin\theta - y \cos\theta$$

$$y' = x \cos\theta + y \sin\theta$$

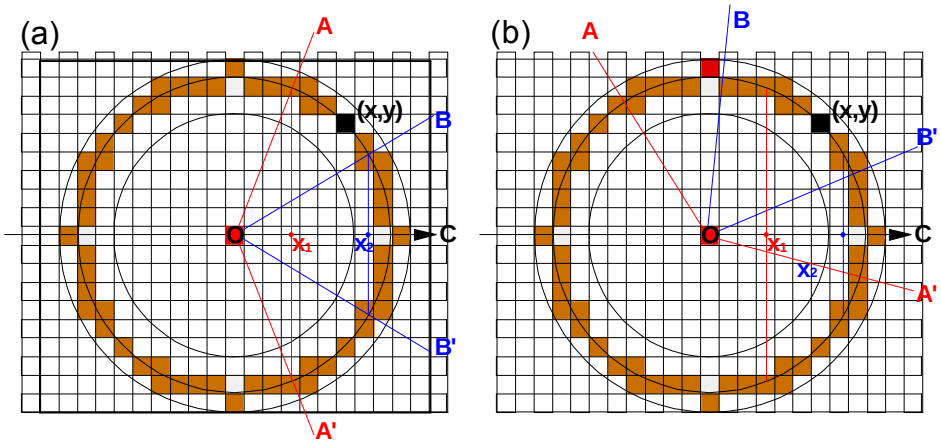


Fig. 50

B2.3 ScanFINECellClose

```
bool AGENT::ScanFINECellClose(CELL* Cell, short XDim, short YDim,
                              AGENT*  Agent[AGENTTYPENB],short iAgentNb[AGENTTYPENB],
                              OBSTACLE* Obstacle, short iObstacleNb,
                              bool bYtorus, bool bXtorus, short XPos, short YPos, int iMode)
```

This function is important, as it is used by all the medium-level scan functions described below in section B.2. When the vision angle is not reduced, it first scans the eight adjacent cell (Fig. 51a), then the sixteen pale green cells represented in Fig. 51b. When the vision angle is less that 180°, the function scans the environment as represented in Fig. 51c,d for an agent moving to WEST, and Fig. 51e,f for an agent moving along the diagonal lines, here North-East.

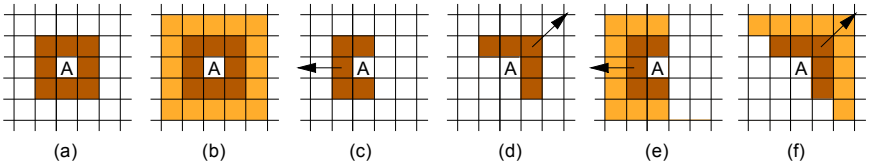


Fig. 51: (a) adjacent cells; (b) Full close environment; (c) adjacent cells in the reduced vision for an agent moving west; (d) adjacent cells in the reduced vision for an agent moving North-East; (e) Full close environment for an agent moving West; (f) Full close environment for an agent moving North-East.

B2.4 ScanFINECellAroundObjects

```
bool AGENT::ScanFINECellAroundObjects(CELL* Cell, short XDim, short YDim,
                    AGENT* Agent[AGENTTYPENB],short iAgentNb[AGENTTYPENB],
                    OBSTACLE* Obstacle, short iObstacleNb,
                    short iDistInit, bool bXtorus, bool bYtorus, int iMode)
```

This function is used to quickly scan the environment. Instead of scanning all cells inside the sense (or the communication) radius, the agent retrieves from its memory the position of the agents founded in the previous cycles (scanning the array `FoundAgents`). Then, it scans around these positions with the previous function `ScanFINECellClose` to identify the new position of the agent. Each scanned cell is analyzed with `CellProcAction.cpp` in the `ACTION` mode or with `CellProcNode.cpp` in the `NODE` mode (see Fig. 52). Additionally, the function also scans the external crown of the agent disk to identify any new agent possibly entering the environment. The speed of the functions `ScanFINECellAroundObjects` and `ScanFINECellRing` is proportional to the numbers of scanned cells, which read respectively:

`ScanFINECellRing`: $N_1 = \pi R_S^2$

`ScanFINECellAroundObjects`: $N_2 = 2\pi R_s \Delta R + 24(1 + N_F)$

When there are few agents in the environment, `ScanFINECellAroundObjects` is faster than the repeated utilization of `ScanFINECellRing` to scan the whole disk. Unfortunately, there is a price to pay, because in some configurations, the function `ScanFINECellAroundObjects` may miss some agents! This situation occurs for instance if the agent disk includes obstacles and if an agent hidden by the obstacles becomes visible. In that case, `ScanFINECellAroundObjects` simply miss it! On the contrary, `ScanFINECellAroundObjects` is slower at high agent density.

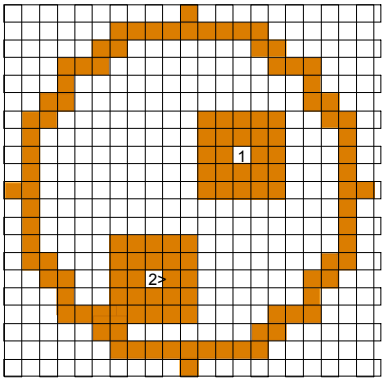


Fig. 52: Example of cells scanned by the function `ScanFINECellAroundObjects` when the agent previously stored the positions labeled 1 and 2 of two objects in its environment.

B2.5 ScanFINECellAroundObjectsSector

```
bool
AGENT::ScanFINECellAroundObjectsSector(CELL* Cell, short XDim, short YDim,
                    AGENT* Agent[AGENTTYPENB],short iAgentNb[AGENTTYPENB],
                    OBSTACLE* Obstacle, short iObstacleNb,
                    short iDistInit, bool bXtorus, bool bYtorus, int iMode)
```

This function operates as `ScanFINECellAroundObjects`, except that before scanning the environment around an agent identified in the previous cycles, it checks that it is located inside the sense angle. This function is used when the vision angle is less than 360°. Considering the direction of our agent and its vision angle, only the “agent-visible” previous agents are processed by this function.

The ACTION cycle (see **Erreur ! Source du renvoi introuvable.** page **Erreur ! Signet non défini.**) shows the general procedure to identify the agent states in the cell scan mode. The script below shows the main function calls when the agent cycle is executed in a DLL (Note: **Erreur ! Source du renvoi introuvable.** in incomplete). Black functions are CORE functions, beyond the scope of this manual. Red, bold underlined functions are entry functions to the DLL, directly called by the CORE (see their description in the CORE Manual). Green functions are DLL functions, called by the entry functions. The indentation reveals the calls. For instance ScanFINECell calls `ScanFINECellMode1` and `ScanFINECellMode2`.

B.3 Scan modes in the NODE cycle

In the `NODE` cycle, the agent always scans its environment to identify the other agents located inside its communication disk. The functions called are exactly the same in the `ACTION` or in the `NODE` mode, except that the CORE calls the sole function `AGENT::ScanFINECellNode` , which is an entry function to the DLL. This function is in the file `ScanFINECellNode.cpp`. The function calls in the `NODE` mode are displayed below:

```
__declspec(dllexport) void AGENT::ScanFINECellNode
          void AGENT::ScanFINECellMode1
              bool AGENT::ScanFINECellClose
                   #include "CellProcNode.cpp"
              bool AGENT::ScanFINECellRing
                   #include "CellProcNode.cpp"
              bool AGENT::ScanFINECellSector
                   #include "CellProcNode.cpp"
          void AGENT::ScanFINECellMode2
              bool AGENT::ScanFINECellClose
                   #include "CellProcNode.cpp"
              bool AGENT::ScanFINECellAroundObjects
                   #include "CellProcNode.cpp"
              bool AGENT::ScanFINECellAroundObjectsSector
                   #include "CellProcNode.cpp"
              bool AGENT::ScanFINECellRing
                   #include "CellProcNode.cpp"
```

Note that all low-level functions call now the behavioral block `CellProcNode.cpp` instead of `CellProcAction.cpp`.

B.4 Simulation results: Prey-predator game

B4.1 Scan mode adjustment

- **CELL scan mode selection**: For each agent, use the `Mode` dropping box. The possible choices are `Circular` (default), `Circular & around agents`, `Automatic`, and `Free for test`.
- **Adjustment of the vision angle**: For each agent population, adjust the vision angle with the `Sense angle` edit box displayed in Fig. 53. The angle is expressed in degrees, adjustable from 10 to 360°.
- **Extension of the vision angle**: The activation of the option entitled `Auto Extend sense angle` (see Fig. 53) makes that the agent increases gradually and symmetrically its vision field when it finds nothing inside its current vision cone. A vision of 360° is more effective than

a vision of 90°, even when the option `Auto extend sense angle` (see Fig. 53) is activated.

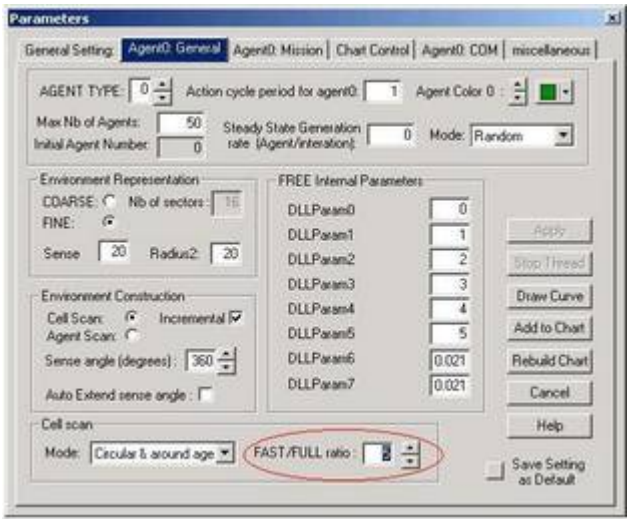


Fig. 53: Adjustement tools of the scan mode in the ACTION cycle

B4.2 Testing the effiency of Policy: 0

- Run `MASS.exe`, then, select the scenario `MASS\CORE\Background1.MAS`. The property page of agents `iAType=0` is shown below.
- In principle, `POLICY: 1` should be selected (see implementation in the mission **Erreur ! Source du renvoi introuvable.** page **Erreur ! Signet non défini.**). If it is not, toggle the `Policy Index` to 1.
- Run the scenario..

The excution of this scenario shows that predators exterminate preys. Of course, that is no surprise. The two next figures show the influence of the scan methods on the predator efficiency and the reduction of the execution time.

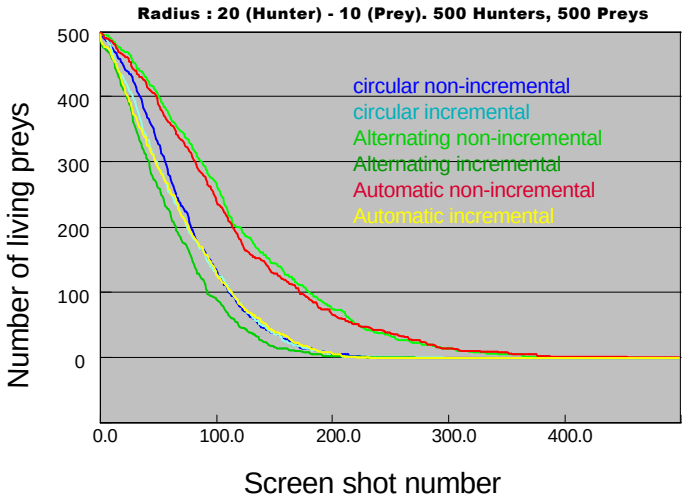


Fig. 54: Comparison of the efficiency of the different scan methods in the prey-predator game.

Color	Mode	Incremental	Time for the 500 iterations
blue	circular	no	1'07
cyan	circular	yes	1'00
green	alternating	no	0'34
dark green	alternating	yes	0'31
red	automatic	no	0'35
yellow	automatic	yes	0'32

Fig. 55: Comparison of the execution times of the different scan methods

The predator radius was 20. The next figure shows the same simulation for a larger predator radius of 50. It is noteworthy to point out that the different non- incremental methods are very closed (blue, red, light-green) as well as the different incremental methods (cyan, green, yellow).

Color	Mode	Incremental	Time for the 500 iterations
blue	circular	no	5'19
cyan	circular	yes	4'36
green	alternative	no	2'03
dark green	alternative	yes	1'44
red	automatic	no	2'02
yellow	automatic	yes	1'45

Fig. 56

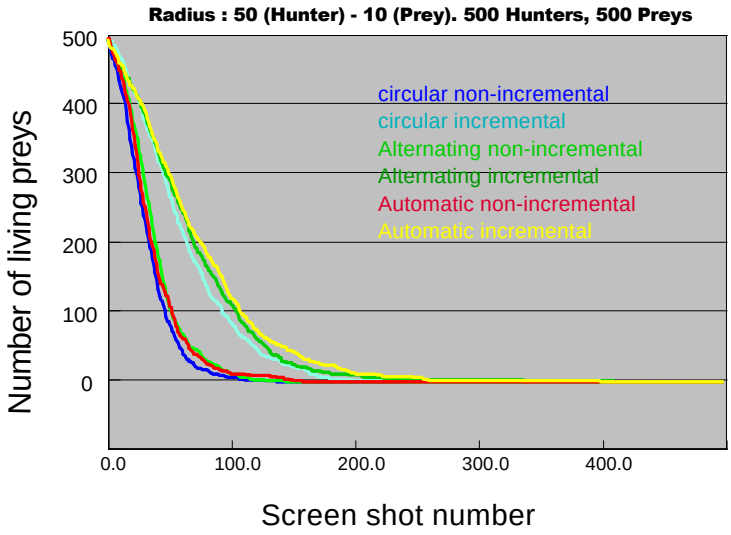


Fig. 57: Comparison of the efficiency of the different scan methods in the prey-predator game.

The next figure show the decay of the number of living preys for various vision angles.

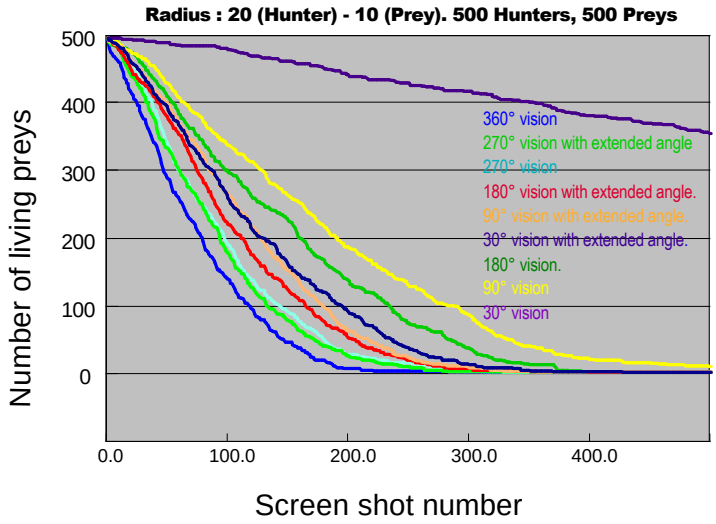


Fig. 58: Comparison of the decay of the number of living preys versus various vision modes

C Environment construction: Cell scan, COARSE representation

C.1 Routines for COARSE representation

We restrict the analysis to `AGENT0` as the con clusions are similar for `AGENT1`. In the COARSE mode, the CSM constructs the representation with the following routines, which are member functions of the AGENT class:

```
void AGENT::COARSECellScan (virtual function)
bool AGENT::COARSECellCloseScan_0
bool AGENT::COARSECellRingScan_0
void AGENT::COARSECondenseZoneInfo
```

Concretely, the construction method consists in scanning the cells in the container square and in determining whether each cell is included in a particular zone, as defined in Fig. 44, page 128. If it is, the number of agents (or obstacles) of the zone is incremented (i.e.,+1) in accordance with the zone occupation field, i.e., the field `COARSEEnviron[0].Zone[i].iAgent1Nb` for agent of type `iAType=0`, or `COARSEEnviron[0].Zone[i].iAgent2Nb` for agents of type `iAType=1`.

Mapping cells to zones is time consuming (particularly for far zones because we must compare the cell location to the angular definition of the zone), we use lookup tables. Lookup tables are build one single time during the configuration phase of `MainTest` (see Fig. 15 page 58). The lookup table store which zone (ρ,θ) contains each cell of relative coordinates (X,Y) in the container square (see Fig. 44). The `LookUpTable` is a 1D table or 2-component vectors declared as follows:

```
short (*LookUpTable1)[2];
short iDimContainer=(2*Radius[iRadius1Nb-1]+1)*(2*Radius[iRadius1Nb-1]+1);
//NOTE THAT LookUpTable IS A 1-D ARRAY TO STORE A 2D ARRAY (i,j)
LookUpTable = new short [iDimContainer][2];
```

where `IDimContainer` is the number of cells in the container square, for instance 120 in Fig. 44. The following relations identify the zone for each cell:

- `LookUpTable1[X*iDimContainer+Y].[0]` is the coordinate ρ of the zone containing the cell of relative Cartesian coordinates `(X,Y)`.Possible values are therefore 0,1,2,3. The program returns –1 when no zone contains the cell, typicall for the cells for the cellsnclose to vertices of the container square.
- `LookUpTable1[X*iDimContainer+Y].[1]` is the coordinate θ of the zone containing the cell of relative Cartesian coordinates `(X,Y)`.

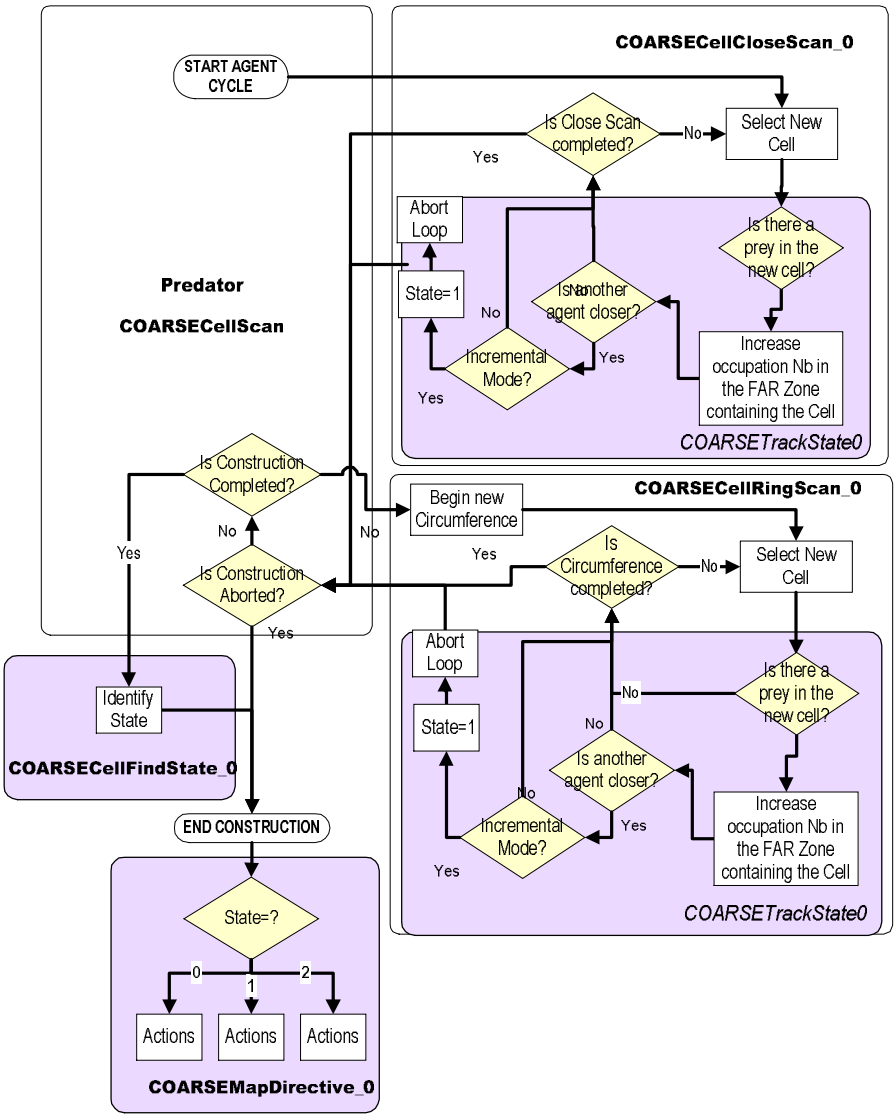


Fig. 59: Predator cycle in the **COARSE** representation mode using the Circular Construction of the environment. The test “Is another agent close” depends on the agent policy (see predator policies, page168).

Note that `LookUpTable` is a one-dimension table to store information on cells in the container square, i.e., on a 2-dimension array. We clarify the storage by considering several examples in Fig. 60:

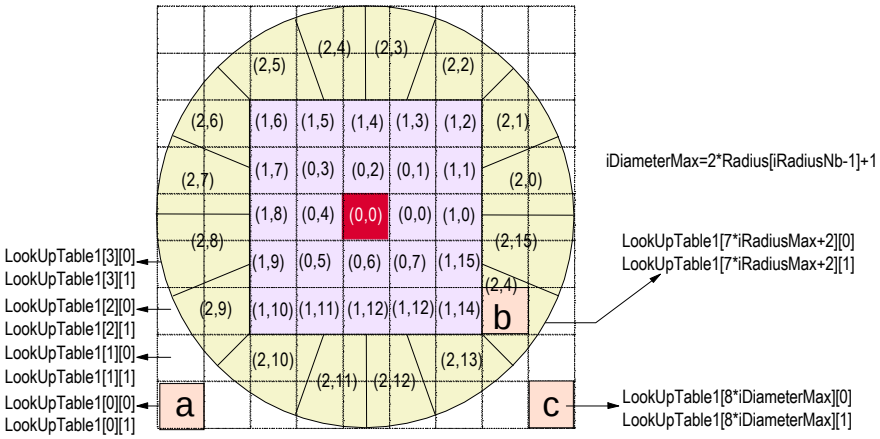


Fig. 60: *Correspondence in the lookup table*

- The polar coordinates (ρ,θ) of the zone containing the left bottom cell (cell a) are stored in `LookUpTable[0]` with ρ=`LookUpTable1[0][0].` As this cell is outside the largest circle, we chose to write `LookUpTable1[0][0])=-1` to code that this cell is outside the zones of the environment. The cell just above *cell a* is stored in `LookUpTable[1]` and so on.
- The polar coordinates (ρ,θ) of the zone containing the cell *b* are stored in `LookUpTable1[7x9+2].`As, cell b is in the angular sector (2,4) (see Fig. 60), ρ=`LookUpTable1[7x9+2][0]=2` and θ=`LookUpTable[7x9+2][1]=4.`
- The zone (ρ,θ) containing the cell c are in `LookUpTable1[8x9+0][0].` As cell c is outside the environment (see Fig. 60), `LookUpTable1[7x9+2][0]=-1.`

Once the lookup table has been built, it is possible by quickly scanning the cells in the container square to deduce the occupation of all the far zones of the environment. The code to build the **far** neighborhood is in the function: `void AGENT::BuildFarZone.`

C1.1 Hidden Agents

Agents in the container square hidden by obstacles are counted in no representation (COARSE or FINE mode). The code is in the member function Agent::IsObstacle().

D Environment construction: Agent scan

The previous construction methods (CSM) built the environment representation by scanning the cells around the agent in the sense disk of radius R. The agent scan mode (ASM) scans agent arrays in the memory of the computer, and identifies the agents inside the sense radius to build the environment representation. This method is faster at low agent densities. To compare the two methods, let us consider the limit case when the whole sense disk is scanned because the construction is not incremental or because the agent does not succeed in identifying an environment state.

- The CSM scans approximately $(2R[2]+1)^2$ cells. The overhead to construct the representation quickly increases with the radius R[2] of the environment.

- The ASM scans the populations of agents (N_{A1} , N_{A2}, N_{A3}, etc..) and obstacles N_{ob} to identify which agents are in the sense disk.

Comparing the two methods, we deduce that ASM is faster than the CSM if:

$$N_{Ob} + \sum_i N_{Ai} < (2R[2]+1)^2$$

The ASM is faster than the CSM when the number of agents is small or when the sense radius is large. This situation corresponds typically to predators tracking a small number of preys. In that case, the predators rarely finds the prey and must complete the whole scan of their environment in the CSM. With N_A=500, the ASM ought to be faster if the radius is larger than 15! Perhaps, the most attractive property of the ASM is that the construction time of the environment representation is independent of the sense radius of the agent.

D.1 Routines for FINE representation

The following routines are used to construct the FINE representation of the environment in the agent scan mode.

```
FineAgentZoneScan (virtual function)
FineAgentZoneScan_0
```

Following the environment construction, there two additional phases, corresponding to the identification of states (`function FINEAgentFindState_0`) and the mapping of directives to states (`FINEMapDirective_0`, which is commun with the FINECellMode).

Note that the CSM and the ASM call the function `FineAction0` and `FineAction1`.

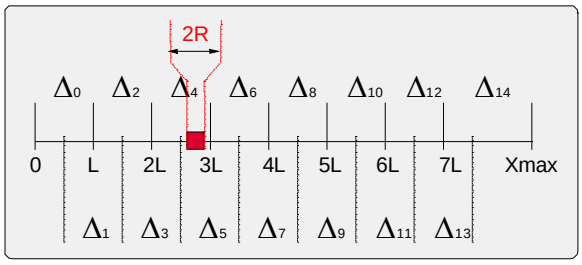
Acceleration of the ASM at high agent density

The ASM ought to be still dramatically accelerated by partitioning the terrain in subsquares and in building a table, which identifies the agents in each square. Then, the method reduces to identifying the square comprising an agent, and scanning the square.

Let us consider for simplicity the problem of identifying the agent environment in a simple segment [0,Xmax] that we partition in a set of subintervals Δ_i:

$$\Delta_i = \left[\frac{L}{2}i, \frac{L}{2}i + L\right]$$

In fact we define two sets intervals as shown in the next figure. Even intervals Δ_0, Δ_2, etc… are adjacent and interlaced with odd intervals Δ_1, Δ_3… Note that the last interval may be larger than L, up to 2L-ε.



In which interval is the environment represented by the red square of side 2R in the figure? If the environment is small, such that 2R<L/2, it is always at least in one interval Δ_i. Let X be the position of the agent in the middle of the red square. The index i *of the interval containing the agent is defined by:* $i = (2X - L/2)\%L$ *where % represents the integer division. Examples: if the agent is such that X∈[0,3L/4], then i=0. If X∈[3L/4,5L/4[, then i=1. If X>(7L+L/4), then, i=14 corresponding to the last interval.*

Therefore, It is possible to partition the interval [0,X_{max}] with the intervals Δ_i *and to simply identify the interval containing the agent environment. Practically, the length L of interval* Δ_i *must verify* ***L≥2R+2,*** *where R is the radius of of the environment. The number 2 is added to make sure that the interval is two times larger than the environment diameter. The number* N_Δ *of intervals is:* $N_\Delta = X_{MAX}\%(2R+2)$

The 2-dimension case is easily deduced from this example. The terrain is now divided by a set of squares Δ*. The numbers of squares in the directionsv X and Y are respectively:*

$$N_X = X_{MAX}\%(2R+2),\quad N_Y = X_{YAX}\%(2R+2)$$

The total number of squares in $N=N_X.N_Y$*. The square (i,j) contains all points (X,Y) such that:*

$$X \in \left]\frac{L}{2}i, \frac{L}{2}i + L\right] \quad Y \in \left]\frac{L}{2}j, \frac{L}{2}j + L\right]$$

The agent of coordinates (X,Y) is in the square: $i = (2X - L/2)\%L$, $j = (2Y - L/2)\%L$ *. Thus it is necessary to scan the agents located in this square to construct the agent environment in the framework of the ASM.*

This approach forces to construct a lookup table which maps the agents in the squares Δ.

Chapter

9

Management of DLLs

We detail the CORE functions, which control the evolvement of the simulation and the calls to the DLL entry functions. We also describe the classes, which decode the mission script.

We assume that you already read the DLLs manual, which describes in details how writing DLLs.

A Action and node cycles

Non-communicating agents execute the sole ACTION cycle as displayed in Fig. 15 page 58. Communicating agents are more complex. They execute the ACTION cycle (as non-communicating agents) and the NODE cycle.

- In the ACTION mode, the agent scans as previously its environment and its internal variables to decide an action. The novelty is that a communicating agent also asks its node to sort the messages in the input buffers before deciding and action. Finally, it may also decide to send new messages as a consequence of its policy.
- In the NODE mode, the communicating agent scans its environment to identify the other agents inside the communication radius. Then, it scans its input buffers to process the incoming messages. The node processing consists in reemitting the message for other nodes detected inside the communication radius, in transfering to a buffer for local processing, in detecting errors in the message… etc

To operate asynchronously in the two modes, each agent has two event times. The ACTION time (represented by the variable `AGENT::ActionTime[0]`) and the NODE time (represented by the variable `AGENT::NODE::NodeTime[0]`) are incremented with the variable `DActionTime` and `DNodeTime`, respectively. MASS is now equipped with two schedulers as represented in Fig. 61.

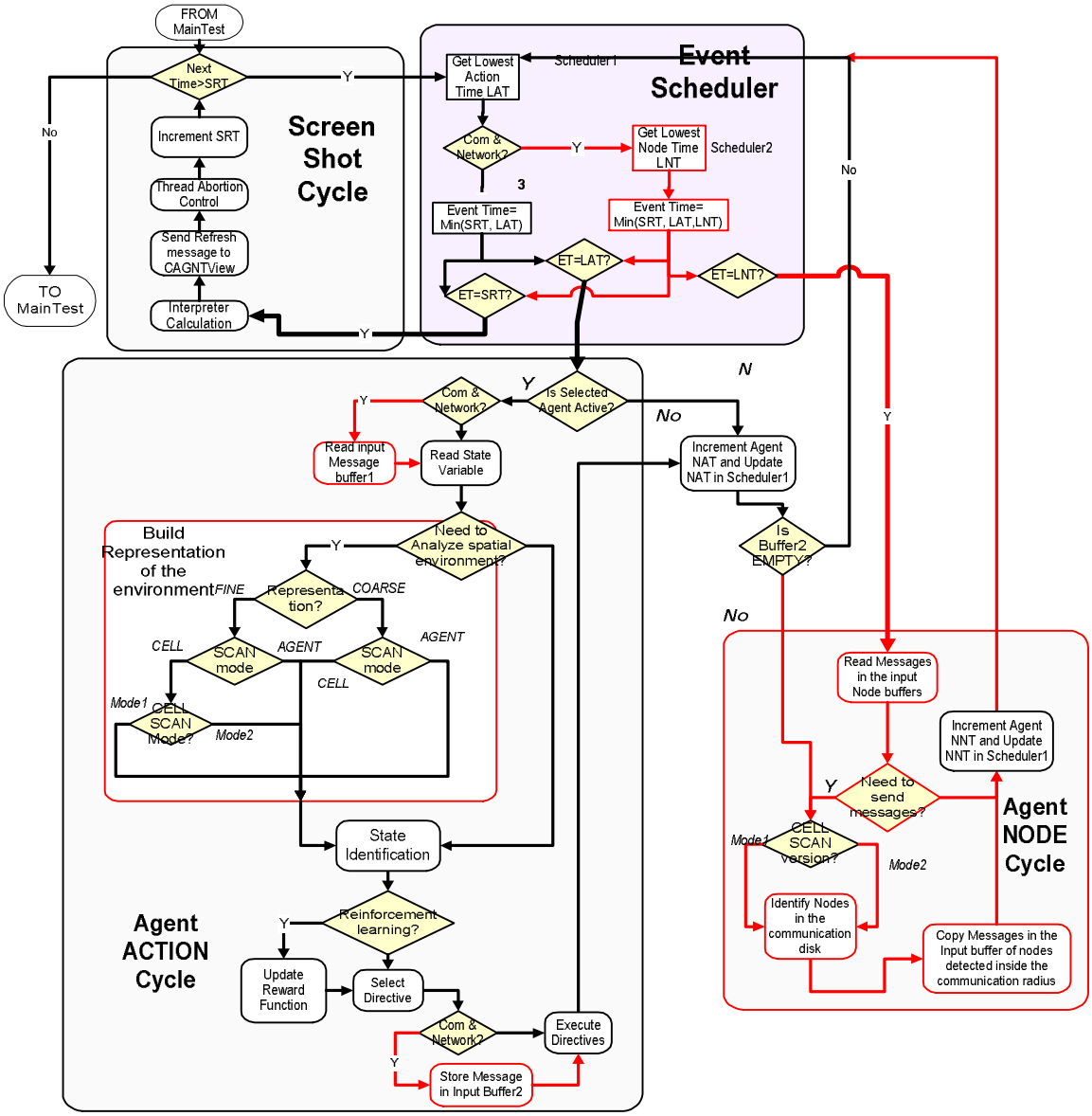


Fig. 61: Flowchart of the function `MainAsynchronous` for a communicating agent; Compare with Fig. 15 page 58 for a non-communication agent.

It is particularly instructive to compare the different representations of the agent cycle reported throughout the manuscript. The AC was first represented as a black box in **Erreur ! Source du renvoi introuvable.** and Fig. 12. Then, Fig. 14 page 54 displayed a partial representation of the AC implementation in the FINE CELL scan mode, restricted to the function `AGENT0::FINECellScan`.

B Call of entry functions to the DLL

Recall that the calculation thread executes the function `ThreadProc`, which calls the function `void MainTest(COREDATA* pData)` (see the thread synchronization principles described in paragraph G page 56). Then, this function calls in the asynchronous mode the function `void MainTestAsynchronous(COREDATA* pData)`, which calls the functions `void ActionMode(..)` or `void NodeMode(..)` to execute an ACTION or a NODE cycle, respectively. The script below details the function calls when the ACTION or NODE cycles are executed in a DLL. **Black** functions are CORE functions when **Green** functions are entry functions to the DLL, directly called by the CORE.

```
ThreadProc
  MainTest
     if (pData->bSynchronous==TRUE) {
        MainTestSynchronous
     }
     else {
        MainTestAsynchronous
            BuidlLookUpTable
            #include "EiCInitialization.cpp"
            NodeMode
                BuildSpatialEnvNODE
                CellScanNet
                    ScanFINECellNode
                AgentScanNet
                .................................
                NODE::DllModifyMsg
                NODE::DllProcessing
                NODE::OutPolicy
                .................................
            ActionMode
                BuildSpatialEnvACTION
                    if (AgentA::bMissionDLL==TRUE) {AGENT::BuildEnvACTION}
                    else AgentA::BuildEnvACTION_CORE
                FindState
                    if (AgentA::bMissionDLL==TRUE) {DllFindState }
                    else AGENT::FindState
                CELLScan
                    if (AgentA->bMissionDLL==TRUE) {
                       AgentA::ScanFINECellAction
                       AgentA::DLLCoarseCellScan
                    }
                    else {
                       AgentA::FINECellScan
                       AgentA::COARSECellScan
                    }
                AGENTScan
                    if(AgentA::bMissionDLL==TRUE) {
                       AgentA::DLLFineAgentScan
                       AgentA::DLLCoarseAgentScan         }
                    else {
                       AgentA::FINEAgentScan
                       AgentA::COARSEAgentScan
                    .................................}
            if (!pData->bFuncInDLL) {     #include "EiCExecution.cpp }
            else {GraphFunc}
            Update
```

```
            ..................................
      }
                  ..................................
          ..................................... etc..
```

Script. 3; Function calls in the main loop of mass. Green functions are calls to entry functions of the DLL

Note that the CORE knows neither what happens in each DLL nor how the DLL functions are customized to generate the agent behavior as requested by the application. **It calls the entry functions listed in Script. 3, and considers that the different agents always execute the same entry functions to DLLs!** Simply, for each agent, the CORE calls the entry functions in the right DLL identified by the handle module `AGENT::DLLhm`, because each agent has a reference to its bevioral DLL[14]. Unfortunately, this "nice" approach generates two complications:

- As user-defined DLLs are selected at runtime, during a "customization" phase, DLLs cannot be loaded immediately on startup[15]. This constraint eliminates the static-link method of DLLs that is extremely simple, and reduces to including the DLL lib file in the client project for simple linkage.
- Dynamic link is necessary. It consists in loading explicitly the DLLs (with the `LoadLibrary` instruction) and in finding the address of the member functions in the DLL (with the function `GetProcAddress`). Unfortunately, the determination of the function address is complicated when one tries to export member functions from DLLs. This issue comes from the fact that the C++ compilers generate decorated names for DLL functions, and that there is no standardization so that each compiler generates its own decorated names making the call of DLLs complicated (to say the least) when the code is compiled with different compilers.

The procedure to call dynamically members functions in the DLL is detailed in Appendix A1 page 200. The code of the function CELLScan below shows (in the grayed zones) the dynamic link to the entry functions in the agent DLL.

```
void CELLScan(AGENT* AgentA,                    //POINTER SHIFTED TO THE RIGHT AGENT
              AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
              OBSTACLE* Obstacle, short iObstacleNb,
              Short (*LookUpTable)[2],          //LOOKUP TABLE FOR Agent1
              CELL* Cell, short XDim, short YDim,
              bool  bXTorus, bool bYTorus,
              short iEnvironmentMode,           //COARSE OR FINE
              short MaxRadius, short MinRadius)
////////////////////////////////////////////////////////////////////////////////
//      ROUTINE TO CONSTRUCT THE ENVIRONMENT THROUGH THE SCAN OF THE CELLS SUR-
//      ROUNDING THE AGENT
////////////////////////////////////////////////////////////////////////////////
{
    if (iEnvironmentMode==COARSE) {
        AgentA->COARSEShiftState();
        if (AgentA->bMissionDLL==TRUE) {//SIMULATION WITH DLLs
        ////////////////////////////////////////////////////////////////////////
            //MAP TO AGENT::DllCOARSECellScan IN DLL. USE MANGLE NAME IN DLL.def
            typedef void (AGENT::*PCOARSECELLSC)(CELL* Cell,short XDim,short YDim,
            AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                        OBSTACLE* Obstacle, short iObstacleNb,
                        bool bXTorus, bool bYTorus,
                        short (*LookUpTable)[2],//LOOKUP TABLE FOR Agent1
                        short MaxRadius,short MinRadius);
```

[14] *so that, most of the time, any agent can execute any DLL.*

[15] *Default DLLs (if loaded on startup) must unloaded to select another behavioral DLL!*

```
            PCOARSECELLSC pCoarseCellSc = force_cast<PCOARSECELLSC>
                     (GetProcAddress((HINSTANCE) AgentA->DLLhm,"CoarseCellScan"));
            if (pCoarseCellSc==NULL)
                ::MessageBox(NULL,"FAILURE FOR pCoarseCellSc ALLOCATION","",MB_OK);
           ((AgentA)->*pCoarseCellSc)(Cell,XDim,YDim,
                                      Agent,iAgentNb,
                                      Obstacle,iObstacleNb,
                                      bXTorus,bYTorus,
                                      LookUpTable,MaxRadius,MinRadius);
        }
        else {  //SIMULATION WITH THE CORE AND THE DEFAULT GAME
            AgentA->COARSECellScan(Cell,XDim,YDim,  //COARSECellScan IS virtual
                                   Agent,iAgentNb,
                                   Obstacle,iObstacleNb,
                                   bXTorus,bYTorus,
                                   LookUpTable,MaxRadius,MinRadius);
        }
    } ////////////////////////////////////////////////////////////////////////////////
    else if (iEnvironmentMode==FINE) {
        AgentA->FINEShiftState();
        if (AgentA->bMissionDLL==TRUE) {//SIMULATION WITH DLLs
        ////////////////////////////////////////////////////////////////////////
        //MAP TO AGENT::ScanFINECell IN DLL. USE MANGLE NAME IN DLL.def
            typedef void (AGENT::*PFINECELLSC)(CELL* Cell,short XDim,short YDim,
                         AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                         OBSTACLE* Obstacle, short iObstacleNb,
                         bool bXTorus, bool bYTorus,
                         short MaxRadius,short  MinRadius);
            PFINECELLSC pFineCellSc = force_cast<PFINECELLSC>
                (GetProcAddress((HINSTANCE) AgentA->DLLhm,"FineCellScanAction"));
            if (pFineCellSc==NULL)
                ::MessageBox(NULL,"FAILURE FOR pFineCellSc ALLOCATION","",MB_OK);
            ((AgentA)->*pFineCellSc)(Cell,XDim,YDim,
                                     Agent,iAgentNb,
                                     Obstacle,iObstacleNb,
                                     bXTorus,bYTorus,
                                     MaxRadius,MinRadius);
        }
        else {  //SIMULATION WITH THE CORE AND THE DEFAULT GAME
            AgentA->FINECellScan(Cell,XDim,YDim,//FINECellScan IS virtutal
                                 Agent,iAgentNb,
                                 Obstacle,iObstacleNb,
                                 bXTorus,bYTorus,
                                 MaxRadius,MinRadius);
        }
    }
}
```

The CORE executes internal agent functions when the DLL linkage is not selected,

C Mission script decoding

C.1 Script

We recall that the way an agent executes its mission is described by a mission script (see the DLLs Manual). A typical mission script is represented below.

```
MISSION: A0 attacks A1, A1 flees A
```

```
*********************************
POLICY: 0

BASIC STATES (S: Spatial; I: internal):
S0: Agent1 detected
S1: NO Agent1 detected, Agent0 detected
S2: NO Agent1 detected, NO Agent0 detected
END1

DIRECTIVES:
M0: Move to Agent1
M1: Move away from Agent(s)0
M2: Move Alone
END2

STATE-DIRECTIVE TABLE:
S0: 100%[M0];0%[M1];0%[M2]
S1: 10%[M0];70%[M1];20%[M2]
S2: 0%[M0];90%[M1];10%[M2]
END3

STATE VARIABLES
VAR0: Energy;2.0;3;1;1.5;2
END4
```

Script. 4: Example of MISSION Script

It is divided in 4 sections beginning respectively with the keywords **BASIC STATES**, **DIRECTIVES**, **STATE-VARIABLE TABLE, STATE VARIABLES** and ending with the delimiter keywords END1, END2… which are mandatory. In the current version, **MASS only decodes the two last sections entitled STATE-DIRECTIVE TABLE and STATE VARIABLES**. The rest of the script is nothing but information for the programmer to identify the mission. The STATE-DIRECTIVE TABLE means:

Line 1 means: Following the identification of state of index 0 (i.e., S0), the agent executes the action of index 0 (i.e. M0)

Line 2 means: Following the identification of state of index 1 (i.e., S1), the agent chooses the action of index 0 (i.e., M0) with probability 10%, or the action of index 1 (Ii.e., M1) with probability 70%, or the state of index 2 (i.e., M2) with probability 20%

Line 3 means: Following the identification of state of 3 (i.e., S3), the agent chooses the action of index 1 (i.e., M1) with probability 90%, or the action of index 2 (i.e., M2) with probability 10%

C.2 Class SCRIPTPROCESSOR

The class SCRIPTPROCESSOR[16] decodes and encapsulates the information initially stored in the mission script. In general, the mission script may includes several policies. Each one is stored in an instance of the class APOLICY (with A for agent) described below in section C.3. Thus, SCRIPTPROCESSOR includes the array {APolicy[i]| 0≤f <m_iAgentPolicyNb} of APOLICY objects, one per policy. The header of the class SCRIPTPROCESSOR is listed below:

```
class SCRIPTPROCESSOR
```

[16] *This class and its subclasses were written by Frédéric Zermano in Jan-Feb 2003*

```
{
   public:

   CString   m_MissionStr;      //FULL MISSION STRING
   CString   m_MissionNameStr;
   int       m_iAgentPolicyNb; //NB OF AGENT POLICIES. REMEMBER THAT EACH AGENT
                               //MAY HAVE SEVERAL POLICIES (DEFINED IN THE MISSION
                               //SCRIPT) AND THAT EACH AGENT POLICY IS THE SUM
                               // OF STATE POLICIES.
   APOLICY*  APolicy;                  //ARRAY OF AGENT POLICIES
   void operator=(const SCRIPTPROCESSOR &other);
   bool DecodeMissionString(CString MissionStr);

   + a list of methods...
};
```

SCRIPTPROCESSOR calls the method `bool DecodeMissionString(CString MissionStr)` to decode the script and to create dynamically the array of agent policies.

C.3 Class APOLICY (Agent policy)

C3.1 Definition

This class is declared as follows:

```
class APOLICY      //AGENT POLICY
//////////////////////////////////////////////////////////////////////////////
// THE CLASS APOLICY (AGENT POLICY) STORES ALL INFORMATION THAT CAN BE RETREIVED FROM
// THE DECODING OF THE MISSION SCRIPT FOR EACH POLICY
//////////////////////////////////////////////////////////////////////////////
{

public:
      CString   m_StateStr;          //STATE STRING DISPLAYED IN A RichEditCtrl
      CString   m_StateVariablesStr; //STATE VARIABLE STRING DISPLAYED IN A RichEditCtl
      CString   m_StateActionStr;    //STATE-ACTION STRING DISPLAYED IN A RichEditCtrl
      CString   m_DirectiveStr;      //DIRECTIVE STRING DISPLAYED IN A RichEditCtrl

      //VARIABLES FOR EACH AGENT POLICY
      int       m_iStateNb;      //NUMBER OF STATES IN THE "BASIC STATES" SECTION OF THE
                                 //THE AGENT POLICY SCRIPT
      int       m_iStateVarNb;   //NB OF STATE VARIABLES IN THE CURRENT POLICY
      CString*  m_StateVarName;  //NAMES OF THE STATES OF THE CURRENT POLICY, UNUSEFUL?
      int*      m_iSamplePtNb;   //NUMBER OF SAMPLE POINTS FOR EACH STATE VARIABLE
      float*    m_StateVar;      //INITIAL VALUES OF STATE VARIABLES
      VARDATA*  m_VarData;       //VarData[i]: OBJECT TO STORE THE SAMPLE POINTS NEEDED
                                 //TO ANALYZE THE STATE VARIABLES
      SPOLICY*  m_SPolicy;       //WARNING: THE AGENT POLICY IS AN ARRAY OF STATE
                                 //POLICIES! THE CLASS POLICY IS A CLASS TO ENCAPSULATE
                                 //ONE SINGLE STATE POLICY
      APOLICY();
      ~APOLICY();
      void operator=(const APOLICY &other);
      void CheckAll();

};
```

This header shows that the object APOLICY includes member variables to describes the policy STATE variables (`m_iStateVarNb`, `m_iSamplePtNb`, `m_StateVar`, `m_VarData`), the number

of states (m_iStateNb) and the policy for each state (m_SPolicy). Note that m_SPolicy is an array of State policies (class SPOLICY) of dimension m_iStateNb. There is one state policy per BASIC STATE in the mission script.

C3.2 Construction

The method bool DecodeMissionString(CString MissionStr) first retrieves the member strings m_StateStr, m_StateVariablesStr, m_StateActionStr, m_DirectiveStr (from MissionStr) for each agent policy.

Example 1: Let us consider the agent policy represented below. We assume that this policy is to be encapsulated in APolicy[0]:

```
BASIC STATES (S: Spatial; I: internal):
S0: Agent1 detected
S1: NO Agent1 detected, Agent0 detected
S2: NO Agent1 detected, NO Agent0 detected
END
DIRECTIVES:
M0: Move to Agent1
M1: Move away from Agent(s)0
M2: Move Alone
END2
STATE-DIRECTIVE TABLE:
S0: 100%[M0];0%[M1];0%[M2]
S1: 10%[M0];70%[M1];20%[M2]
S2: 0%[M0];90%[M1];10%[M2]
END3
STATE VARIABLES:
VAR0: Energy; 2.0;4.0;0.5;1;1.5;2
END4
```

Fig. 62

DecodeMissionString will initialize the member variables of APolicy[0] as follows:

```
//GetStateStrings() RETREIVES THE "BASIC STATE" STRING FOR EACH AGENT POLICY
//DEFINED IN THE MISSION SCRIPT. THUS, IT RETRIEVES APolicy(0).m_StateStr,
//APolicy(1).m_StateStr,… FOR THE AGENT POLICY OF INDEX 0, WE DEDUCE:
APolicy[0].m_StateStr =" S0: Agent1 detected \nS1: NO Agent1 detected, Agent0
                        detected \nS2: NO Agent1 detected, NO Agent0 detected"

//GetStateVariableString() RETREIVES THE "STATE VARIABLE" STRING FOR EACH AGENT
//POLICY DEFINED IN THE MISSION SCRIPT. FOR POLICY OF INDEX 0, WE GET:
APolicy[0].m_StateVariablesStr = "VAR0: Energy;2.0;3;1;1.5;2"

//GetStateDirectiveString() RETREIVES THE "STATE-DIRECTIVE TABLE" STRING FOR EACH
//AGENT POLICY DEFINED IN THE MISSION SCRIPT. FOR THE POLICY OF INDEX 0, WE GET:
APolicy[0].m_StateActionStr = "S0: 100%[M0];0%[M1];0%[M2] \nS1:
            10%[M0]; 70%[M1];20%[M2] \nS2: 0%[M0];90%[M1];10%[M2]";

//GetDirectiveStrings() TO RETREIVE THE "DIRECTIVE" STRING FOR EACH AGENT POLICY
//DEFINED IN THE MISSION SCRIPT. FOR THE POLICY OF INDEX 0, WE GET:
APolicy[0].m_DirectiveStr= "M0: Move to Agent1 \nM1: Move away from
                            Agent(s)0 \nM2: Move Alone"

//GetNumberOfSpatialStates(int i) RETREIVES THE NUMBER OF STATES FOR FOR THE //POLICY
OF INDEX i. FOR THE POLICY OF INDEX 0, WE GET:
APolicy(0).m StateStr=3;

m_iDirectiveNb=3;         //TOTAL NB OF POSSIBLE DIRECTIVES IN THE CURRENT POLICY

//GetNumberOfStateVariable(int i) RETREIVES THE NB OF VARIABLES IN THE POLICY //OF
INDEX i.
APolicy(0).m_iStateVarNb=1;
```

```
//GetNamesOfStateVariables(int i) TO RETREIVE THE NAMES OF STATE VARIABLES IN //THE
POLICY OF INDEX i.
   APolicy(0].m StateVarName;

//GetNbOfSamplesForEachVariable(int i) RETREIVES THE NB OF SAMPLES PER //STATE
VARIABLE IN THE POLICY OF INDEX i.
APolicy(0].m iSamplePtNb;

//GetInitialValueOfStateVariable(int i) RETREIVES THE INITIAL VALUES THE STATE
VARIABLE IN THE POLICY OF INDEX i.
     APolicy(0].m_StateVar;
```

C.4 Class VARDATA

The class VARDATA stores the sample points used to analyze the behavior of the state variable (see the section STATE VARIABLES in Script. 4 page 155). The class APOLICY includes an array of VARDATA objects, one per state variable. VARDATA is declared as follows:

```
class VARDATA
////////////////////////////////////////////////////////////////
// CLASS TO STORE THE DATA NECESSARY TO ANALYSE EACH STATE VARIABLE
////////////////////////////////////////////////////////////////
{
      public:
            int iDataPtNb;
            float* DataPt;
            VARDATA();
            ~VARDATA();
            void operator=(const VARDATA &other);
            void Build(int XDataPtNb, float* XDataPt);
      protected:
             void GetInterval(float X);
};
```

The method VARDATA.Build(…) reads the state variable string and copies the sample points in the dynamic array DataPt[iDataPtNb].

C.5 Class SPOLICY (State policy)

C5.1 Definition

The class SPOLICY encapsulates the state policy, which stores the set of directives (with their respective probabilities) that can be executed when the agent has recognized its state. It is explicitly defined by one line in the section STATE-DIRECTIVE STABLE of the mission script. The class SPOLICY is declared as follows:

```
class SPOLICY      //STATE POLICY
////////////////////////////////////////////////////////////////////////////////
// THE CLASS SPOLICY REPRESENTS THE POLICY FOR ONE STATE. THE AGENT
// POLICY IS AN ARRAY OF STATE POLICIES, ONE PER STATE.
////////////////////////////////////////////////////////////////////////////////
{
      public:
      int m_ActionNb; //NB OF POSSIBLE ACTIONS
      int* m_Action;  //ACTION ARRAY. FOR INSTANCE m_Action[2]=5 MEANS THAT THE
                      //THIRD POSSIBLE ACTION WHEN THE ENVIRONMENT IS IN THIS
```

```
                    //STATE IS THE ACTION OF INDEX 5
      float* ActionValue;       //ACTION VALUE IN LEARNING MECHANISM
      float* m_Proba;           //VALUE OF THE POSSIBLE ACTIONS.

      SPOLICY();
      ~SPOLICY ();
      void operator=(const SPOLICY &other);
      void Build( int* Action, int iActionNb, float* ActionValue);
      int SelectAction();
};
```

C5.2 Construction

The method `DecodeMissionString(CString MissionStr)` calls the method `bool` **`SCRIPTPROCESSOR::`**`DecodeAgentPolicyString(int i)` for each agent policy. This method first splits the string `APolicy[i].m_StateActionStr` (see the example 1 just above) in state policy strings (the array `SPolicyStr`, see the code), where the string `SPolicyStr[i]` corresponds to the line of index *i* in `m_StateActionStr`. Then, it calls `SCRIPTPROCESSOR::DecodeStatePolicyString` to decode all strings `SPolicyStr[i]`, to determine `APolicy[0].m_SPolicy[i].m_ActionNb` and the arrays `APolicy[0].m_SPolicy[i].m_Action[j]` and `APolicy[0].m_SPolicy[i].m_Proba[j]` with $0 \leq$ `APolicy[0].m_SPolicy[i].m_ActionNb`.

Example 2: Let us consider the first agent policy already described in example 1. The State-Action string for this agent policy was:

```
APolicy(0).m StateActionStr=       "S0: 100%[M0];0%[M1];0%[M2] \nS1:
            10%[M0]; 70%[M1];20%[M2] \nS2: 0%[M0];90%[M1];10%[M2]";
```

`DecodeAgentPolicyString(int i)` will define the policy strings:

```
SPolicyStr[0]="S0: 100%[M0]; 0%[M1]; 0%[M2]"
SPolicyStr[1]="S1:  10%[M0];70%[M1];20%[M2]"
SPolicyStr[2]="S0:   0%[M0];90%[M1];10%[M2]"
```

`DecodeStatePolicyString(int i)` will define the arrays:

```
APolicy[0].m_SPolicy[0].m_ActionNb=3;
APolicy[0].m_SPolicy[0].m_Action[0]=0;
APolicy[0].m_SPolicy[0].m_Proba[0]=1;
APolicy[0].m_SPolicy[0].m_Action[1]=1;
APolicy[0].m_SPolicy[0].m_Proba[1]=0;
APolicy[0].m_SPolicy[0].m_Action[2]=2;
APolicy[0].m_SPolicy[0].m_Proba[2]=0;

APolicy[0].m_SPolicy[0].m_ActionNb=3;
APolicy[0].m_SPolicy[1].m_Action[0]=0;
APolicy[0].m_SPolicy[1].m_Proba[0]=0.1;
APolicy[0].m_SPolicy[1].m_Action[1]=1;
APolicy[0].m_SPolicy[1].m_Proba[1]=0.7;
APolicy[0].m_SPolicy[1].m_Action[2]=2;
APolicy[0].m_SPolicy[1].m_Proba[2]=0.2;

APolicy[0].m_SPolicy[2].m_Action[0]=0;
APolicy[0].m_SPolicy[2].m_Proba[0]=0.1;
APolicy[0].m_SPolicy[2].m_Action[1]=1;
APolicy[0].m_SPolicy[2].m_Proba[1]=0.9;
APolicy[0].m_SPolicy[2].m_Action[2]=2;
APolicy[0].m_SPolicy[2].m_Proba[2]=0.1;
```

Note that `APolicy[0].m_SPolicy[2].m_Action[2]=12` would mean that the third possible action (i.e., directive) for the state of index 2 will be the

directive M12 in the "DIRECTIVE" section of the mission script, which in this example must include at least 12 directives.

C5.3 State identification and directive selection

We assume here that you are familiar with the writing of DLLs. The state recognition in `CellProcAction.cpp` (or in `ScanDecisionTree`) is always followed by these two generic lines.

```
int  value=DLLSelectAction(FINEStateParam[0]);
(this->*PolicyFunctions[value])(FINEStateParam,Cell,XDim,YDim,Move);
```

The first line calls the following agent `int AGENT::DLLSelectAction(int iStateIndex)` (the code of which is listed below), which calls the method `int SPOLICY::SelectAction()`.

```
int AGENT::DLLSelectAction(int iStateIndex)
////////////////////////////////////////////////////////////////////////////
//SELECT THE ACTION, POSSIBLY USING REINFORCEMENT LEARNING
////////////////////////////////////////////////////////////////////////////
{
     switch( iLearnMode ) {
        case -1:        //NO LEARNING MECHANISM
             return this->APolicy.m_SPolicy[iStateIndex].SelectAction();
             break;
        case 0:
             //YOUR CODE HERE TO CALCULATE REWARD FUNCTION

             //YOUR CODE HERE TO UPDATE ACTION VALUES FOR THE PREVIOUS STATE

             //UPDATE ACTION PROBABILITIES IN THE PREVIOUS STATE POLICY
             ::MessageBox(NULL,"CODE NOT WRITTEN","AGENT::SelectAction",MB_OK);
             return 0;
             break;
    }
    ::MessageBox(NULL,"IRREGULAR TERMINATION","AGENT::SelectAction",MB_OK);
     return 0;  //
}
```

The code of `SPOLICY::SelectAction()` is listed below.

```
int SPOLICY::SelectAction()
////////////////////////////////////////////////////////////////////////////
// INFORMATION
// THE FUNCTION SELECTS ONE OF THE ACTIONS IN THE SET OF m_ActionNb ACTIONS
// AND FINALLY IDENTIFIES THE ACTION IN THE FULL SET OF ACTIONS
////////////////////////////////////////////////////////////////////////////
{
        int i;
        if (m_ActionNb==1) return this->m_Action[0];
        //STEP 2: SELECT ONE OF THE POSSIBLE ACTIONS FROM A RANDOM TEST
        float Test = (float) (1.0*rand()/(1.0+RAND_MAX));
        float Threshold=m_Proba[0];
        for (i=0;i<m_ActionNb;i++) {
               if (Test<Threshold) break;
               else Threshold=Threshold+m_Proba[i+1];
        }
        //RETURN THE ACTION INDEX
        return this->m_Action[i];
}
```

The method `SelectAction()` selects an action in the array of the `m_ActionNb` possible actions, which are in the state policy and finally **returns the index of the action in the full action table**. Note that this step is purely logical, independent of the reality of states and actions.

C.6 Initialization of mission scripts on startup

MASS (i.e., the CORE) always loads default scripts on startup, one per agent. The default mission scripts are returned by following methods:

```
CString CAGNTView::DefaultMissionScript0()    for agent iAType=0
CString CAGNTView::DefaultMissionScript1()    for agent iAType=1
CString CAGNTView::DefaultMissionScript2()    for agent iAType=2
CString CAGNTView::DefaultMissionScript3()    for agent iAType=3
CString CAGNTView::DefaultMissionScript4()    for agent iAType=4
CString CAGNTView::DefaultMissionScript5()    for agent iAType=5
```

In the current version, they describe the prey-predator game. Global initialization of all variables is executed in `void CAGNTView::OnInitialUpdate()`, which calls

```
void CAGNTView::BuildAgentPopulations()
```

which finally creates one instance of SCRIPTPROCESSOR, (one per agent class) from

```
ScriptP[0].DecodeMissionString(DefaultMissionScript0());
ScriptP[1].DecodeMissionString(DefaultMissionScript1());
                        Etc..
```

Explicitely, `ScriptP[0].DecodeMissionString(DefaultMissionScript0())`, decodes the mission string for agent iAType=0, i.e., creates the instance of SCRIPTPROCESSOR for the agent class iAType=0, using the default script returned

by `DefaultMissionScript0`.

D Elimination of closed cycles

Closed cycles become an issue at low agent density, i.e., when agent-agent collisions are unable to redistribute the agent directions. Two types of closed cycles are possible:

- Two-reflection cycles occur when an agent is reflected under normal incidence by the borders. In that case, it moves vertically or horizontally in an infinite cycle.
- Four-reflection cycles occur when the agent is reflected in the diagonal directions (northwest, northeast, southeast and southwest). In that case, it enters a diamond-like cycle.

Reflections on obstacles and borders (as borders are obstacles) are detected by the function `AGENT::DetectCycle(bool DropOrMain, int Diagonal)`. The operation is simple:

- First, `DetectCycle()` systematically stores the coordinates of the last reflection points in the arrays `ReflectPtX[REFLECTIONNB]` and `ReflectPtY[REFLECTIONNB]`. In the current version `REFLECTIONNB =10` (see `GLOBAL.h`). The last reflection is stored in

`ReflectPtX[0], ReflectPtY[0]`. The coordinates of the previous reflection points are stored in `ReflectPtX[0], ReflectPtY[0]`, those of the previous reflection poinrq in `ReflectPtX[1], ReflectPtY[1]` and so on…

- Second, `DetectCycle()` checks whether it previously stored the last point into its arrays. if it is, the agent is inside a Closed Cycle and `DetectCycle()` switches the Boolean member variable `AGENT::ClosedCycle` to true.

The detection of the close loop is executed when the agent moves and calls the functions `void AGENT::FINEMoveAlone2` or `void AGENT::FINEMoveToCell`. The loop breaking is executed during the next agent activation by the function `AGENT::BreakClosedLoop()`, which is integrated in `MainTest`. This function operates as follows::

- It randomly initializes a counter `iCountNb` between 0 and 100.
- The counter is decremented of 1 units in each agent iteration. When `iCountNb=0`, `MainTest` randomly changes the agent direction.

The detection of closed cycles in the torus mode requires a specific treatment because there is no reflection at all. It is possible to trace the previous directions of the agent as they are stored in the two arrays `ShiftX[ITERATNB]` and `ShiftY[ITERATNB]`, which are updated so that (`ShiftX/Y[0]` is copied to `ShiftX/Y[1]`, `ShiftX/Y[1]` to `ShiftX/Y[2]`, and so on…) in AGENT::BreakClosedLoop()while the current iteration is stored to ShiftX/Y[0] in AGENT::FINECell/AgentScan and AGENT::COARSE Cell/AgentScan.

In the torus mode, AGENT::DetectCycle(bool DropOrMain, int Diagonal) is called by MainTest, and check how many times the agent has moved in the same direction. When this value is bigger than Diagonal, this function put the boolean ClosedCycle to true.

E Implementation of reinforcement learning mechanisms

E.1 Introduction

In a reinforcement learning process, the programmer defines the states that the agent recognizes, the state policies (i.e., the actions that the agent considers following each state) and an optimization function (Reward function). These are to some extend the static properties. Reinforcement learning algorithms are dynamic mechanisms that adapt the actions chosen by the agent (i.e., the agent policy) to bring quickly the agent in high-reward states.

E.2 Action value algorithms

In the action value algorithms (AVA), each action is scored by a value number. The value estimates how good the action is with respect to the agent mission. The value estimation is based on the following mechanism:

1) The agent executes an action a_p using the current values $\{Q_n(S,a_i)|0\leq i<N_a\}$ of the possible actions (n is the iteration index and N_a is the number of possible action following S). The AVAs differ in the way the agent uses the current action values $Q_n(S,a_i)$ to select an action.

2) Later, the agent identifies its environment, and calculates the reward function R_{n+1}. The reward function depends on the current environment state. It is used to update the value of the previous action (as the agent remember its previous action a_p and it previous state S):

$$Q_{n+1}(S,a_p)=Q_n(S,a_p)+\alpha\left(R_{n+1}-Q_n(S,a_p)\right)$$

The AVAs also differ in the way the coefficient α is chosen.

The execution of a reinforcement learning session (RLS) is therefore composed of an initialization procedure followed by a dynamic adjustment of the policy. These two phases are described below:

INITIALIZATION PHASE

Step 1: Define the environment and states to represent the environment. This step can be especially difficult when the number of states is infinite, as some method will have to be defined to reduce the computation overhead. The solution generally consists in using some abstraction to reduce the number of states. Moreover, the way the environment is defined often deeply influences the actions that can be defined.

Step 2: Define the set of possible actions (In principle, the set of possible actions is unchanged during the RLS).

Step 3: For each state, define the set of possible actions with their initial probabilities. This initialization may reflect the programmer expertise to provide a minimum efficient policy to the agent. The neutral initialization consists in affecting the same value to all actions.

Step 4: Define a reward function to appreciate how a state is close to the execution of the mission. The reward function is crucial.

Table 2

The next table represents two examples of reinforcement learning algorithm.

ITERATIVE PHASE : ε-greedy algorithm)

Step 0: Consider iteration *n+1*.

Step 1: Observe the reaction of the environment, and construct the representation S_{n+1} of the environment. In general, the environment is the product of the spatial state by the state of agent variables.

Step 2: Calculate the reward R_{n+1}.

Step 3: Then, update the action value for the action a_p selected at the previous iteration n:

$$Q_{n+1}(S,a_p)=Q_n(S,a_p)+\alpha\left(R_{n+1}-Q_n(S,a_p)\right)$$

with $0\leq\alpha\leq1$. Alternatively, one may use $\alpha=\frac{1}{n+1}$, where n is the number of selections

of action a_p following *S* since the beginning the test learning procedure. In this method, Q_{n+1} is the average reward..

Step 4: Identify the greedy action following state *S*, i.e., the action a_{iMax}, which has the top estimated action value $Q_{n+1}^{\pi}(S,a)$ among all possible actions following the identification of state *S*.

Step 5: Choose the greedy action with probability (1-ε) and another action with probability $\varepsilon/(N_a-1)$, where N_a is the number of possible actions following S.

Step 6: Go to step 1.

Table 3

ITERATIVE PHASE (pursuit algorithm)

Step 0: We consider iteration *n+1*.

Step 1: Observe the reaction of the environment, and construct the representation S_{n+1} of the environment. In general, the environment is the product of the spatial state by the state of agent variables.

Step 2: Considering the previous state S_n and the current state, S_{n+1}. Determine the reward $R_{n+1}(S_n,a_i)$ obtained choosing the a_i when the environment was in at previous iteration.

Step 3: Then, update the action value for the action a_i selected at the previous iteration *n*:

$$Q_{n+1}(S,a_p)=Q_n(S,a_p)+\alpha\left(R_{n+1}-Q_n(S,a_p)\right)$$

with $0\leq\alpha\leq1$. Alternatively, one may use $\alpha=\frac{1}{n+1}$, where *n* is the number of selections of action a_p following *S* since the beginning the test learning procedure. In this method, Q_{n+1} is the average reward.

Step 4: Identify the greedy action following state *S*, i.e., the action a_{iMax}, which has the top estimated action value $Q_n^{\pi}(S,a)$ among all possible actions following the identification of state *S*.

Step 5: Update the probability $\pi_{n+1}(S_n,i)$ to select the next action a_i:

$$\pi_{n+1}(S_n,i)=\begin{cases}\pi_n(S_n,i)+\beta(1-\pi_n(S_n,i)) & \textit{for the greedy action}\\ \pi_n(S_n,i)-\beta\pi_n(S_n,i) & \textit{for any other action}\end{cases}$$

with $\beta<0$. Note that, the greedy solution increases to 1, when iterating the process.

Step 6: Select an action a_i. using the above probabilities and execute the action.

Step 7: Go to step 1.

Table 4

E.3 Implementation of action value algorithms

The agent has several member variables and methods to implement AVAs. The next lines show the relevant declarations in the agent header:

```
////////////////////////////////////////////////////////////////////////////
//REINFORCEMENT LEARNING VARIABLES ANDS FUNCTIONS
   APOLICY      APolicy;            //AGENT POLICY
      int       iLearnMode;         //iLearnMode<0 MEANS NO LEARNING
      int       iRewardMode;        //TO SELECT A METHOD TO CALCULATE THE REWARD
      int       iPreviousState;     /STATE IDENTIFIED AT PRECEEDING AGENT ACTIVATION
      int       iPreviousAction;    //ACTION SELECTED AT PRECEEDING AGENT ACTIVATION

      float     Reward();           //METHOD TO CALCULATE THE REWARD
      float     DLLReward();        //
      int       SelectAction(int iStateIndex);
      int       DLLSelectAction(int iStateIndex);
   ////////////////////////////////////////////////////////////////////////////
```

Consider an agent, which executes a mission defined in a DLL. When the agent is activated by the scheduler, it first constructs a representation of its environment and identifies a state. Recall that a state is nothing but a Bolean condition involving the environment and the agent state variables. The state is labeled by a state index, in accordance with the agent mission string. In general, the state index is stored in the agent member variable `FINEStateParam[0]`. The rest of the agent cycle depends on wether learning mechanisms are integrated.

- When **no** learning method (LM) is implemented, (i.e., when the member variable `iLearnMode<0`), the agent calls the method `DLLSelectAction` to select an action in the state-directive tables.
- When, an AVA algorithm is implemented (`iLearnMode>=0`), the agent: 1) calculates the reward function `AGENT::Reward()` (which requires knowing the current state); 2) Updates the action value $Q(S_{n-1},a_{n-1})$ (which requires knowing the previous state S_{n-1} and the previous action a_{n-1}); 3) Updates the probability to select $a_{n-1}Q$ from S_{n-1}, and finally 3) calls the method `DLLSelectAction` to select an action in the state-directive tables. Remember that:
  - The class SPolicy includes the array `float* ActionValue` to store the action values of all possible actions (see the class declaration in section C.5 page 158).
  - The agent remembers its previous state and its previous action, which it stores in its member variables `iPreviousState` and in `iPreviousAction`, respectively.
  - The ActionValue, which must be updated is therefore:

    `APolicy.m_SPolicy[iPreviousState].ActionValue[iPreviousAction]`
  - The action probability, which must be updated is therefore:

    `APolicy.m_SPolicy[iPreviousState].m_Proba[iPreviousAction]`

The code of the member function `AGENT::DLLSelectAction` is displayed below. Note that the call parameter is the state index (`StateIndex`), which must have been identified prior to calling this function.

```
int AGENT::DLLSelectAction(int iStateIndex)
////////////////////////////////////////////////////////////////////////////////
//SELECT THE ACTION, POSSIBLY USING REINFORCEMENT LEARNING
////////////////////////////////////////////////////////////////////////////////
{
   switch( iLearnMode ) {
       case -1:      //NO LEARNING MECHANISM
          return this->APolicy.m_SPolicy[iStateIndex].SelectAction();
          break;
```

```
      case 0:
         //CALCULATE REWARD FUNCTION
         //UPDATE ACTION VALUES FOR THE PREVIOUS STATE. THE AGENT STORES THE VARIABLES
         //iPreviousState AND iPeviousAction. THE ACTION VALUE TO UPDATE IS THEREFORE
         //APolicy.m_SPolicy[iPreviousState].ActionValue[iPreviousAction]
         //UPDATE ACTION PROBABILITIES IN THE PREVIOUS STATE POLICY, I.E., UPDATE:
         //APolicy.m_SPolicy[iPreviousState].m_Proba[iPreviousAction]
         ::MessageBox(NULL,"CODE NOT WRITTEN","AGENT::SelectAction",MB_OK);
         return 0;
         break;
   }
   ::MessageBox(NULL,"IRREGULAR TERMINATION","AGENT::SelectAction",MB_OK);
   return 0;      //
}
```

E.4

Chapter 10

Chapter history:
Version 1.0, April-June 2009 by JHC and Jaroslaw Wojciechowski

Extension for 3D simulations

This chapter describes the changes added in the code of the core and of DLLs to enable 3D moves of agents.

MASS was initially designed as a 2D simulator, and consequently; agents move in a plane. This chapter shows the changes which were added in Spring 2009 to the CORE and to DLLs to enable agents to move in a 3D space. Concretely, an agent has two coordinates X and Y and move in a 2D array of cells. The changes consists in adding one more coordinate Y and in enabling the torus mode in the new direction. We first describe the extension of several classes.

A Extension of structures and classes

We describe in this section the extension of several classes and structures to enable 3D moves of agents. Note that extending an object to prepare future developments is risk-free and that all existing code should recompile and run smoothly!

A.1 Structure COREDATA

Recall that the structure COREDATA is the memory shared by the CORE and all DLLs, as it is the call parameter for each worker thread. Recall that this structure is extensively described in section B page 16. It has been modified to enable 3D moves. The part entitled "SECTION 3: TERRAIN" of the structure COREDATA (see SECTION 3 page 17) becomes:

```
////////////////////////////////////////////////////////////////////////
//SECTION 3: TERRAIN
      short   XDim;          //X DIM OF THE TERRAIN
      short   YDim;          //Y DIM OF THE TERRAIN
  //CODE ADDED BY JAREK WOJCIECHOWSKI TO ENABLE 3D 3D MOVES
→    short   ZDim;           //Z DIM OF THE PLAYGROUND
→    short   iPlaneIndex;      //FROM 1 to XDIM, YDIM, ZDIM      (NEW)
→    short   iWhichPlane2D;    //0:XY,1:XZ,2:ZY                  (NEW)
```

```
→   bool    b_show_alllayers;  //SHOWS ALL AGENTS IN ALL LAYERS IGNORING iPlaneIndex
(NEW)

     CELL*   Cell;          //THE TERRAIN IS A RECTANGULAR ARRAY OF CELL OBJECTS
     bool    bXtorusMode;   //if TRUE, NO X BORDER, CYCLIC CONDITION
     bool    bYtorusMode;   //if TRUE, NO Y BORDER, CYCLIC CONDITION
→    bool    bZtorusMode; ; //if TRUE, NO Z BORDER, CYCLIC CONDITION   (NEW)
     short   iteratNb;
```

Script 17: Extension of the COREDATA structure for 3D moves

The changes consist in defining the dimension ZDim in the Z direction, in enabling the torus mode in the new direction and in adding the `short iPlaneIndex; short iWhichPlane2D;` to be used by paint functions and manipulated by the user interface controls. `iPlaneIndex` is denoting which level of one of three plains to paint in the 2D graph and `iWhichPlane2D` is denoting which plain to show (D paragraph).

A.2 Class AGENT

The AGENT class has been extended to add one more coordinate to the agent position which is now defined by the triplet (X,Y,Z). The 2D agent class declaration (i.e., the agent header `Agent.h`) displayed in section D6.1 page 23 has been modified accordingly. The extended `SECTION I: GENERAL VARIABLES` is displayed below.

```
class AGENT (May 2009)
////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////
{
  public:
   ////////////////////////////////////////////////////////////////////////////
   SECTION I : GENERAL VARIABLES
    short X;                    //X POSITION OF THE AGENT IN THE GRID
    short Y;                    //Y POSITION OF THE AGENT IN THE GRID
→short Z;                      //Z POSITION OF THE AGENT IN THE GRID (NEW)
    short ShiftX[ITERATNB];     //ARRAY TO STORE THE LAST X SHIFT OF THE AGENT;
                                //SHIFT PER ITERATION IS EQUIVALENT TO THE SPEED!!!
    short ShiftY[ITERATNB];     //ARRAY TO STORE THE LAST Y SHIF OF THE AGENT
    //CODE AJOUTE PAR JAREK WOJCIECHOWSKI
→short ShiftZ[ITERATNB];   //ARRAY TO STORE THE LAST Z SHIF OF THE AGENT (NEW)
    ..............
    etc.....
}
```

Additionnally, we extended the number of call parameters of numerous member functions. The principle of the extension is simple:

- When a member function of the class `AGENT` contains the dimensions `XDim` and `YDim` in the 2D plane, we added a new call parameter `ZDim` which is the dimension in the Z direction.
- When a member function of the class `AGENT` contains the positions `iTCell` and `jTCell` of the agents in the 2D plane, we added a new call parameter `kTCell` that will be its position in the Z direction.
- When a member function of the class `AGENT` contains the bXTorus and bZTorus option for X and Y axis, we added a new call parameter bZTorus that will be torus option for Z axis.

Note that adding call parameters which are unused at this step of the development makes that all member functions automatically work. We preserve the ascending compatibility.

```
class AGENT
////////////////////////////////////////////////////////////////////
{
   ..............
public: (NEW CALL PARAMETERS OF MEMBER FUNCTION ARE HIGHLIGHTED IN RED)
//MEMBER FUNCTION TO STORE NODES IN FoundNode
void FINEStoreNodeInArray( short iType,short iTCell,short jTCell, short kTCell,
                           short Index,
                           bool bXtorus, bool bYtorus, bool bZtorus,
                           short XDim, short YDim, short ZDim);

//SCAN THE CELLS OF THE ENVIRONMENT IN THE FINE MODE FOR NETWORK OPERATION
  declspec(dllexport)
void ScanFINECellNode(CELL* Cell,short XDim,short YDim,short ZDim,
                      AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                      OBSTACLE* Obstacle, short iObstacleNb,
                      bool bXTorus, bool bYTorus, bool bZTorus,
                      short MaxRadius,short MinRadius);
//FUNCTIONS USED WHEN THE SPATIAL ENVIRONMENT CONSTRUCTION IS NOT NEEDED
virtual BOOL BuildEnvACTION_CORE(CELL* Cell, short XDim, short YDim,short ZDim,
                                 AGENT* Agent[AGENTTYPENB],short iAgentNb[AGENTTYPENB],
OBSTACLE* Obstacle, short iObstacleNb,bool bXTorus,bool bYTorus);//,bool bZTorus

virtual void FindState(CELL* Cell,short XDim,short YDim,short ZDim,
AGENT* Agent[AGENTTYPENB],      short iAgentNb[AGENTTYPENB],
bool bXTorus, bool bYTorus, bool bZTorus);
////////////////////////////////////////////////////////////////////////////////
…
//ARRAY OF FUNCTIONS TO MAP WITH MOVE FUNCTIONS.
void (AGENT::* PolicyFunctions[POLICYFUNCTIONNB])
(short* MoveParam,CELL* Cell,short XDim,short YDim,short ZDim, MOVE* Move);
//UTILITY FUNCTIONS
…
//SERVICE FUNCTIONS
bool KillPrey(…short ZDim,…);
void UpdatePosition(…short ZDim,…);
//INTERFACE FUNCTIONS IN MISSION DLLs
__declspec(dllexport) void ScanFINECellAction(…short ZDim, …,bool bZtorus,…);
__declspec(dllexport) BOOL BuildEnvACTION(…short ZDim, …,bool bZtorus,…);
__declspec(dllexport) BOOL BuildEnvNODE(…short ZDim, …,bool bZtorus,…);
__declspec(dllexport) void DllFindState(…short ZDim, …,bool bZtorus,…);
__declspec(dllexport) void DllCOARSECellScan(…short ZDim, …,bool bZtorus,…);
__declspec(dllexport) void DllFINEAgentScan(…short ZDim, …,bool bZtorus,…);
__declspec(dllexport) void DllCOARSEAgentScan(…short ZDim, …,bool bZtorus,…);
//FUNCTIONS IN THE MISSION DLLs REPULSIVE_1_3D EXCLUSIVELY
bool ScanFINECellClose_3D(CELL* Cell, short XDim, short YDim, short ZDim,
                    AGENT*      Agent[AGENTTYPENB],   short iAgentNb[AGENTTYPENB],
                    OBSTACLE* Obstacle, short iObstacleNb,
                    bool bYtorus, bool bXtorus, bool bZtorus,
                            int iMode);
bool ScanFINECellRing_3D(CELL* Cell, short XDim, short YDim,short ZDim,
                    AGENT*      Agent[AGENTTYPENB],   short iAgentNb[AGENTTYPENB],
                    OBSTACLE* Obstacle, short iObstacleNb,
                    short iDistInit, bool bXtorus, bool bYtorus,bool bZtorus,
                          int iMode);
void ScanFINEDecisionTree_3D(CELL* Cell,short XDim,short YDim,short ZDim,
                    AGENT* Agent[AGENTTYPENB], short iAgentNb[AGENTTYPENB],
                    OBSTACLE* Obstacle, short iObstacleNb,
                            bool bXtorus, bool bYtorus, bool bZtorus);
```

```
void FINEStoreInArray_3D(short iType,short iTCell,short jTCell, short kTCell, short
Index,
                    bool bXtorus, bool bYtorus,bool bZtorus,
   short XDim, short YDim, short ZDim);
void FINEMoveAlone2_3D  (short* MoveParam,CELL* Cell,
   short XDim,short YDim,short ZDim,MOVE* Move);
void FINEMoveAway2_3D   (short* MoveParam,CELL* Cell,
   short XDim,short YDim,short ZDim,MOVE* Move);
void FINEStoreNodeInArray_3D(short iType,short iTCell,short jTCell, short kTCell,
   short Index,bool bXtorus, bool bYtorus, bool bZtorus,
   short XDim, short YDim, short ZDim);
          ..............
}
```

Script 18: Listing of modified member function declarations

A.3 Class MOVE

The class MOVE is extended and now includes the shift DZ .The parameter iSect is being interpreted now not only for moves in plain but also for up and down values.

```
class MOVE
////////////////////////////////////////////////////////////////////////
//  AT THE MOMENT, AN ACTION REDUCES TO A SINGLE MOVE. HOWEVER, THE CLASS STRUCTURE
//  COULD BE EXTENDED TO CONSIDER OTHER EFFECTS
////////////////////////////////////////////////////////////////////////
{
    public:
          short DX;      //SHIFT IN X DIRECTION
          short DY;      //SHIFT IN Y DIRECTION
    →     short DZ;      //SHIFT IN Z DIRECTION
          short iSect;   //iSect=0: MOVE EAST; iSect=1: MOVE NORTH EAST; iSect=2: MOVE NORTH;
                         //iSect=3: MOVE NORTH WEST; iSect=4: MOVE WEST; iSect=5: MOVE SOUTH WEST;
                         //iSect=6: MOVE SOUTH; iSect=7: MOVE SOUTH EAST;
                         //MOVE UP OR DOWN IN 3D //iSect=7,8....25
          double weight; //RATE OF THE ACTION
          char mode;     //'U': UNDEFINED; 'M': MOVE; 'K': MOVE & KILL
};
```

Script 19: Listing of modified class MOVE

A.4 Class CPointEx

This class is also extended and now includes the z position of the Cell.

```
class CPointEx
{

public:
          double x;
          double y;
    →     double z;

          CPointEx();
          CPointEx(float X, float Y);
          CPointEx(float X, float Y,float Z);
          void operator = (const CPointEx &other);
          bool operator == (const CPointEx &other);
          bool operator != (const CPointEx &other);
```

```
};
```

Script 20: Listing of modifications in class CPointEx

B Changes to read, display and write scenarios

B.1 Reading scenario file

Recall that the first action executed by the user when he (she) runs MASS consists in selecting and reading an existing scenario. A scenario is nothing but a XML file. When the user selects a scenario, the CORE executes the function `CAGNTDoc::OnFileOpen()` which calls the member function `CAGNTView::ReadPlaygroundFromXML(&InXML)` to read the XML scenario and retrieve the dimensions `ThreadData.XDim`, `ThreadData.YDim`, and `ThreadData.ZDim` of the terrain. The code changes in the function `CAGNTDoc::OnFileOpen()` are displayed in the script below.

```
void CAGNTDoc::OnFileOpen()
//////////////////////////////////////////////////////////////////////////////
//////////////////////////////////////////////////////////////////////////////
{
    .............
    .............
    pView->ReadPlaygroundFromXML(&InXML); //RETREIVE THE TERRAIN DIMENSIONS!
    .............
    .............
    //////////////////////////////////////////////////////////////////////////
    //BRANCH
    if(pView->ThreadData.ZDim == 1) {
        //CREATES A CXDraft WINDOW (ON TOP OF THE VIEW)
        //WHICH GETS THE FOCUS
        //OLD CODE
        pView->m_draft.ReadXMLFromDisk(szFileName);    //PZAJAC  22-07-2008
    }
    else if (pView->ThreadData.ZDim > 1){
→      pView->m_draft.ReadXMLFromDisk_3D(szFileName); //JWojciechowski  22-04-2009
    }
    //////////////////////////////////////////////////////////////////////////
…   .............
    .............
}
```

Script 21: Modifications in the function `CAGNTDoc::OnFileOpen()`

The next script displays the modifications in the function `pView::ReadPlaygroundFromXML`

```
void CAGNTView::ReadPlaygroundFromXML(XMLNode* InXML)
//////////////////////////////////////////////////////////////////////////////
//      HISTORY: VERSION 1: June 2003, JHC
//                       2: July 2008 PZAJAC
//                    3: April 2009 JWOJCIECHOWSKI // ZDIM,ZTorus
{
//////////////////////////////////////////////////////////////////////////////
        int iProvi;
        InXML->read("MASS:PLAYGROUND:XDIM", iProvi,450);
        ThreadData.XDim = (short) iProvi;
        InXML->read("MASS:PLAYGROUND:XTORUS_MODE", iProvi,1);
```

```
        if (iProvi==1) ThreadData.bXtorusMode=true; else ThreadData.bXtorusMode=false;

        InXML->read("MASS:PLAYGROUND:YDIM", iProvi,350);
        ThreadData.YDim= (short) iProvi;
        InXML->read("MASS:PLAYGROUND:YTORUS_MODE", iProvi, 1);
        if (iProvi==1) ThreadData.bYtorusMode=true; else ThreadData.bYtorusMode=false;

→       InXML->read("MASS:PLAYGROUND:ZDIM", iProvi,1);
        if (iProvi!=NULL && iProvi>0) ThreadData.ZDim= (short) iProvi;
         else ThreadData.ZDim= 1;
→       InXML->read("MASS:PLAYGROUND:ZTORUS_MODE", iProvi, 1);
        if (iProvi==1) ThreadData.bZtorusMode=true; else ThreadData.bZtorusMode=false;
}
```

Script 22: Modifications in the function `CAGNTView::ReadPlaygroundFromXML`

Note the following important points:

- Script 22 shows that when the field `ZDim` is missing in the scenario file, the default value for `ZDim` is 1, and the torus mode in the Z direction is not activated, i.e., `bZTorusMode` = FALSE. These values are set to preserve the ascending compatibility when the new code reads an old 2D scenario.
- We integrated a branch in the function `CAGNTDoc::OnFileOpen()` (see Script 21) to separate the processing of 3D scenarios from that of existing 2D processing. The fundamental idea behind the branch introduction is to avoid mixing old code (for 2D scenario) with the new 3D code.
- The function `ReadXMLFromDisk_3D` is described in C.2 section.

B.2 Changes to generate the agent populations

The function `ReadXMLFromDisk_3D` generates the agents positions in the 3D background (space). Let us recall that **the scenario does not include a list of agent positions, but simply a directive for generating the agent positions**. The code below of the function `ReadXMLFromDisk_3D` shows that the agent generation directive is stored in the member variable `m_Background.iAgentGenMode[i]` for the agent of type `i`. Then, `ReadXMLFromDisk_3D` calls the function `FillOusideObjects_3D` to generate the agents positions.

```
void  CXDraft::ReadXMLFromDisk_3D(CString FileName)
////////////////////////////////////////////////////////////////////////////////
//                    1: April 2009 JWojciechowski
////////////////////////////////////////////////////////////////////////////////
{
    int i,j,k;
    CString Str1="", Str01="";
    CString Str2="", Str02="";
    //XML_ParamIO InXML;
    int iVersionNb;
    ////////////////////////////////////////////////////////////////////////
    CAGNTView* pView=GetActiveView1();
    COLORREF AColor[AGENTTYPENB];
    for (k=0;k<AGENTTYPENB;k++) AColor[k]=pView->AgentColor[k][0];
    int XDim=pView->ThreadData.XDim;
    int YDim=pView->ThreadData.YDim;
       int ZDim=pView->ThreadData.ZDim;
       ////////////////////////////////////////////////////////////////////////
    CClientDC pDC(this);
    CPen* penCur = new CPen(this->iDefaultLineStyle,1,this->iDefaultDrawPen);
    pDC.SelectObject(penCur);
    pDC.SetROP2(R2_NOTXORPEN);
```

```
////////////////////////////////////////////////////////////////////////////////
    RECT rect;
    GetParent()->GetClientRect(&rect);

////////////////////////////////////////////////////////////////////////////////
    XMLNode InXML=XMLNode::openFileHelper(FileName,"MASS");
    ////////////////////////////////////////////////////////////////////////////
    InXML.read("MASS:VersionNb",iVersionNb,0);
    ////////////////////////////////////////////////////////////////////////////
    → //OBSTACLE CODE HAS BEEN REMOVED

    //READ BACKGROUND PARAMETERS                //READ ONLY FOR iVersion>2
    Str1=Str01+"MASS:STARTCONFIG:BACKGROUND";
    for (j=0;j<AGENTTYPENB;j++) {
           Str2=Str1+":AGENT"+CHAR(48+j);
           InXML.read(Str2+":NB",m_Background.iAgentNb[j],0);
           InXML.read(Str2+":GENMODE",m_Background.iAgentGenMode[j],0);← GENERATION MODE!
    }
    InXML.read(Str1+":OBST:NB",m_Background.iObstacleNb,0);
    InXML.read(Str1+":OBST:GENMODE",m_Background.iObstacleGenMode,0);
    m_Background.AgentSize=AgentSize;
    →       m_Background.FillOusideObjects_3D(XDim,YDim,ZDim);
       ////////////////////////////////////////////////////////////////////
   //this->Invalidate();
    GetTotalObjectNb();
       ////////////////////////////////////////////////////////////////////
}
```

Script 23: Code of the function CXDraft::ReadXMLFromDisk_3D

- The code of the generation function `CBackground::FillOusideObjects_3D` is responsible for the generation of Agents in the field outside the obstacles. However, as we have omitted obstacles in the 3D environment, an agent may be placed in any cell of the 3D terrain. The important point is that the `CPointEx` class has been modified to store the Z coordinate for the Cell class (see paragraph A.4 of this chapter).

```
    bool CBackground::FillOusideObjects_3D(int XDim,int YDim,int ZDim)
    ////////////////////////////////////////////////////////////////////////////
    //      HISTORY:       Version 1, April 2009, JWojciechowski
    //      INFORMATION:   FILL UP THE 3D background WITH AGENTS.
    ////////////////////////////////////////////////////////////////////////////
    {
        ..............
    int iPtNb3D=0;
    int SHIFT=0;
    //STEP 1: CALCULATE THE NUMBER OF POINTS int mesh calculated as doubles
        int iBackgroundPtNb3D=iPtNb3D;   //for 3D
    ////////////////////////////////////////////////////////////////////////////
    //NOW, DEFINE THE ARRAY Cell. EACH CELL IS REPRESENTED BY 4, X,Y,empty,Z INTEGER
    NUMBERS.
    //EXTEND PTCOMPONENTNB IF YOU WANT TO DESCRIBE THE CELL WITH MORE NUMBERS
    //int (*Cell)[PTCOMPONENTNB];
    //Cell = new int[iBackgroundPtNb][PTCOMPONENTNB];
         double (*Cell)[PTCOMPONENTNB];
    →    Cell = new double[iBackgroundPtNb3D][PTCOMPONENTNB];
         //CONSTRUCT THE CELLS
         for (i=SHIFT; i<XDim-SHIFT;i++){
            for (j=SHIFT; j<YDim-SHIFT;j++) {

              for (z=SHIFT; z<ZDim-SHIFT;z++) {
                   Cell[iPtNb3D][0]=(1.0*i)/XDim;
```

```
                Cell[iPtNb3D][1]=(1.0*j)/YDim;
                Cell[iPtNb3D][2]=-1;  //DEFAULT:EMPTY;
→               Cell[iPtNb3D][3]=(1.0*z)/ZDim;
     }}}
     //CHECK THAT YOU CAN GENERATE THE NUMBER OF REQUESTED OBJECTS IN THE PLAYGROUND

//%%%
```

In step 2 of the script there is a `iAgentGenMode` variable responsible for generation mode of agents. The generation mechanism is in STEP5. The already generated Z position is copied to `AgentCell` array of the background.

B.3 Changes to ActionCycle of the Agent

```
void ActionMode (COREDATA *pData,
                 AGENT* pAgent,
                 short(*LookUpTable[AGENTTYPENB])[2])
////////////////////////////////////////////////////////////////////////////////
//      HISTORY: Version 1: November 2003, AUTHOR: Julien ALBURQUERQUE
//
//      INFORMATION:
//  THIS FUNCTION REALISE ACTIONS OF THE AGENT WHICH HAS THE SMALLEST NAT
//
//  CODE PREVIOUSLY INCLUDED IN MainTestAsynchronous AND MOVE IN THIS FUNCTION
//  FOR MORE LIGIBILITY
////////////////////////////////////////////////////////////////////////////////
{
     short XDim=pData->XDim;  //NB OF CELL IN THE X DIRECTION
     short YDim=pData->YDim;  //NB OF CELL IN THE Y DIRECTION
     short ZDim=pData->ZDim;       //3D, CODE AJOUTE PAR JWOJCIECHOWSKI
     if (ZDim==1 && pAgent->Z!=0 ){
            pAgent->Z=0;
            ::MessageBox(NULL,"WARNING Z IS INCORRECT!","FROM MAINAsynchronous.cpp",MB_OK);
     }
     //SIZE OF THE DIAGONAL OF THE PLAN
     int Diagonal=(int) sqrt((float)(pData->XDim*pData->XDim+pData->YDim*pData->YDim));
     int iType=pAgent->iAType;
     int iRank=pAgent->iRank;
     if (pAgent->AgentMode=='A')     {                    //AGENT IS ACTIVE
          if(ZDim==1){//only for 2D
              pAgent->BreakClosedLoop();
          }
          ......
          ......
          ......
          //UPDATE CELL STATE: REMEMBER THAT IN THE ASCII TABLE, CHAR(49)='1'
          pData->Cell[pAgent->Z*XDim*YDim+pAgent->X*YDim+pAgent-
>Y].State[0]=CHAR(49+iType);
          //JWOJCIECHOWSKI
          pData->Cell[pAgent->Z*XDim*YDim+pAgent->X*YDim+pAgent->Y].iRank=iRank;
     }
     for (int i=ITERATNB-1;i>0;i--) {
               pAgent->ActionTime[i] = pAgent->ActionTime[i-1];
     }
     // UPDATE NEXT ACTION TIME (NAT)
     pAgent->ActionTime[0] = pAgent->ActionTime[0] + pAgent->DActionTime;

}
```

Script 25: Code of the function **`void ActionMode ()`**

B.4 Changes to generate the obstacles on the borders of the 3D playground

The function `BuildBorder2_3D` is executed in the function `void CParamSheet::ReBuildOstaclePopulation()`. The sequence is as follows: `OnBar1Start()`, then `SaveAndRebuildALL()`, then `ReBuildOstaclePopulation()`, then `BuildBorder2_3D()`

```
void CParamSheet::ReBuildOstaclePopulation()
////////////////////////////////////////////////////////////////////////////////////////
////////////////////////////////////////////////////////////////////////////////////////
{
    CAGNTView* GetActiveView1();
    CAGNTView* pView=GetActiveView1();
    int i;
    COREDATA* pData=&pView->ThreadData;
    ////////////////////////////////////////////////////////////////////
    .........
    .........
    //-------------------------------------------------------------------------------
    -------
    //INITIALIZATION OF POPULATIONS OF OBSTACLE1
       if(pView->ThreadData.ZDim==1){
           BuildBorder2(pData->Cell,pData->XDim,pData->YDim,
                        pData->bXtorusMode,pData->bYtorusMode);
       }else if (pView->ThreadData.ZDim>1){
           BuildBorder2_3D(pData->Cell,pData->XDim,pData->YDim,pData->ZDim,
                           pData->bXtorusMode,pData->bYtorusMode,pData->bZtorusMode);
       }
}
```

Script 26: Code of the function `CParamSheet::ReBuildOstaclePopulation()`

```
  void BuildBorder2_3D(CELL* Cell,    //OCCUPATION STATE OF ALL CELLS IN THE GRID
                       short XDim,    //NUMBER OF CELLS IN THE X DIRECTION
                       short YDim,    //NUMBER OF CELLS IN THE Y DIRECTION
                       short ZDim,
                       bool bXtorus, //bXTorus=true -> NO X BORDER
                       bool bYtorus, //byTorus=true -> NO Y BORDER
                       bool bZtorus)
  ////////////////////////////////////////////////////////////////////////////
  //    THE BORDER LIMITS ARE DEFINED BY OBSTACLES
  //
  ////////////////////////////////////////////////////////////////////////////
  {
        int i;
        if (bXtorus==false) for (i=0;i<XDim;i++) //ADD OBSTACLES TO BUILD THE BORDER
        {
           for(int k=0;k<ZDim;k++){
               Cell[k*XDim*YDim+i*YDim].State[0]='O';
                    Cell[k*XDim*YDim+i*YDim+YDim-1].State[0]='O';
           }
        }
        if (bYtorus==false) for (i=0;i<YDim;i++) //ADD OBSTACLES TO BUILD THE BORDER
        {
           for(int k=0;k<ZDim;k++){
                    Cell[k*XDim*YDim+i].State[0]='O';
                    Cell[k*XDim*YDim+(XDim-1)*YDim+i].State[0]='O';
           }
        }
           if (bZtorus==false) for (i=0;i<XDim;i++) //ADD OBSTACLES TO BUILD THE BORDER
        {
           for(int j=0;j<YDim;j++){
```

```
                Cell[i*YDim+j].State[0]='O';//+j
                Cell[(ZDim-1)*XDim*YDim+i*YDim+j].State[0]='O';
            }
        }
}
```

Script 27: Code of the function **`BuildBorder2_3D`**

B.5 Changes to paint the initial agent populations

B5.1 Generalities

The class `CXDraft` displays the initial populations of agents constructed from the scenario (see the class description in the section entitled Population initialization: DRAFT page 100). Recall that in the current version, 3D scenarios contain no obstacles (thus, also no rectangle, no line, no ellipsis) so that the sole used graphical object of the `CXDraft` class is the background.

We have not developed a sophisticated 3D display of the agent populations. In this version, we use the `CXDraft` class to paint the agents located in a plane. For instance, we may paint the agent in a plane perpendicular to the `Z` direction. We call such a plane a `XY` plane. To identify a `XY` plane, we simply specify its `Z` coordinate that we call the plane index. The plane index is identified by the integer variable `iPlaneIndex`. This approach is transposed for the planes parallel to the `YZ` or `ZX` directions. In all cases, to select a plane, we must define the plane index `iPlaneIndex`, (i.e., the coordinate in the direction perpendicular to the plane) and the plane direction.

B5.2 Selection of the plane and interface modification

The plane selection is executed by means of the new dialog box displayed in Fig. 63, which is an extension of the interface of MASS for 3D scenarios. Moreover, a new bottom with this icon

has been added in the left-toobar to activate this box.

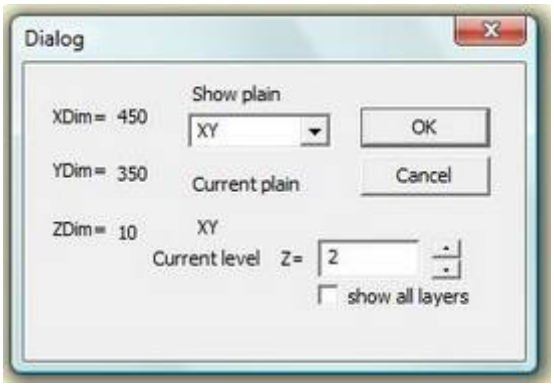


Fig. 63: New dialog box to select the painting plane in the 3D case

The controls in this dialog box allows the user to setup the plane direction and the plane index which are member variables of the COREDATA structure. Explicitly:

- `ThreadData.iWhichPlane2D` is defined with the possible values 0,1 or 2 respectively for `XY`, `XZ`, or `ZY` planes.
- `ThreadData.iPlaneIndex` is defined in the range `1≤iPlaneIndex≤XDim`.

Unfortunately, there a small issue because positions are defined with continuous coordinates in the `CXDraft` class. Thus, we derive a `double` type index `dLevel` to get the plane index in the background of the `CXDraft`. This is a simple proportionality expression. For planes parallel to XY, YZ or ZX, we define `dLevel` respectively as:

```
double dLevel= (1.0*IPlaneIndex-1)/ZDim;
dLevel= (1.0*IPlaneIndex-1)/XDim
dLevel= (1.0*IPlaneIndex-1)/YDim
```

And for absolute coordinate the iLevel is regular number from 3DDlgBox:

```
int iLevel=ThreadData.iLevNbToPaint2D-1;
//with the borders
```

The dialog box allows the user to change the plane direction and the levels of plains to be painted by manipulating the variables in COREDATA : `short iPlaneIndex; short iWhichPlane2D;`. The data are changed by user interface controls. `iPlaneIndex` is denoting which level of one of three plains to paint in the 2D graph and `iWhichPlane2D` is denoting which plain to show.

The dialog box shown in Fig. 63 is associated to the class `CDlg3DBox`, the header of which is displayed below.

```
class CDlg3DBox : public CDialog
    {…
    public:
    CString s XDIM;
    CString s YDIM;
    CString s ZDIM;
    int m iCurrentLevel;
    CString m sCurrentPlain;
    CComboBox m comboPlane;
    CNumSpinCtrl m Spin1 current level;
    HWND ParenthWnd;
    …
}
```

Script 28: Header of the class `CDlg3DBox`

This box is a member variable of the MFC class `AGNTView` and consequently declared as follows in the header `AGNTView.h`:

```
→   CDlg3DBox* m pDlg3DBox;//POINTER TO THE BOX WHEN 3D SPACE IS USED FOR
                           //SIMULATIONS, I.E., WHEN ZDIM>1
```

Note that the pointer `m_pDlg3DBox` MUST be initialized to NULL in the constructor `CAGNTView::CAGNTView()`. This initialization is very important to stability of MFC applications.

When you click the button

in the left toolbar, the core executes te following function which splashes the `CDlg3DBox`.

:

```
void CMainFrame::OnSelect3DBox()
{
    ////////////////////////////////////////////////////////////////////////////
/
    //CODE ADDED BY JWOJCIECHOWSKI. TO PROCESS THE MENU ITEM WINDOW, 3D options
```

```
        ////////////////////////////////////////////////////////////////////////////////
/
        CAGNTView* pView = GetActiveView1();
        if (pView != NULL ) {
            if(pView->m_pDlg3DBox==NULL){
                pView->m_pDlg3DBox=new CDlg3DBox(this);
                pView->m_pDlg3DBox->Create(IDD_DLG_3DBOX,this);
            }
            pView->m_pDlg3DBox->ShowWindow(SW_NORMAL);
            pView->m_pDlg3DBox->Invalidate();
        }
    }
```

Script 29: New function to activate the `CDlg3DBox`

The code below checks whether `ZDim` is larger than 1 to activate this button. Indeed this button must not be activated when the scenario is a 2D scenario.

```
    void CMainFrame::OnUpdateSelect3DBox(CCmdUI* pCmdUI)
    ////////////////////////////////////////////////////////////////////////////
    //CODE ADDED BY JWOJCIECHOWSKI. TO PROCESS THE MENU ITEM WINDOW, 3D options
    ////////////////////////////////////////////////////////////////////////////
    {
        CMDIChildWnd* pActive= MDIGetActive(NULL);
→       if (pActive==NULL) return;
        //if there will not be the check for MDIGetActive then it MASS crashes
        CAGNTView* pView = GetActiveView1();
→       if (pView->ThreadData.ZDim>1){
                pCmdUI->Enable(TRUE); //ENABLE THE BUTTON
                pCmdUI->SetCheck(0);
        }
                else {
                pCmdUI->SetCheck(0);  //UNCHECK BUTTON IN TOOL BAR
                pCmdUI->Enable(FALSE);//DISABLE THE BUTTON BECAUSE NO WINDOW
        }
     }
```

Script 30: Modifications in the function CAGNTView::OnPaint()

Changing the plane orientation controls updates "immediately" the data in the shared structure Threaddata. The code is in the dialog class CDlg3DBox.cpp.

```
    void CDlg3DBox::OnCbnSelchangeComboWhichplain()
    {
                ............
                CAGNTView* GetActiveView1();         //PROTOTYPE
                CAGNTView* pView=GetActiveView1();
                CString str;
                int iPrior=m_comboPlane.GetCurSel();
                if (iPrior==0) {
                        str.Format("XY",NULL);
                CString tmp;
                tmp.Format("%d",pView->ThreadData.XDim);
                s_XDIM=tmp;
                tmp.Format("%d",pView->ThreadData.YDim);
                s_YDIM=tmp;
→               tmp.Format("%d",pView->ThreadData.ZDim);
                s_ZDIM=tmp;
                pView->ThreadData.iPlaneIndex=1;
                pView->ThreadData.iWhichPlane2D=0;
                m_Spin1_current_level.SetDecimalPlaces (0);
                m_Spin1_current_level.SetTrimTrailingZeros (FALSE);
                m_Spin1_current_level.SetRangeAndDelta (1,pView->ThreadData.ZDim,1);
                m_Spin1_current_level.SetPos(1);
```

```
                m_comboPlane.SetCurSel(0);//XY plane
                m_sCurrentPlain="XY";
                m_sCP="Z=";
                ............
     }
}
```

Script 31: Modifications in the function CAGNTView::OnPaint()

The spin control uses the `CNumSpinCtrl` class with `AutoBuddy` behavior property set to True. This property selects the previous control value when the action of the spin is triggered. In the code spin control changes the m_iCurrentLevel edit box which triggers the execution of `void CDlg3DBox::OnEnChangeEdit1m_iCurrentLevel()`:

```
   void CDlg3DBox::OnEnChangeEdit1m_iCurrentLevel()
      {
               int pos=m_Spin1_current_level.GetPos();
               m_iCurrentLevel=pos;

       CAGNTView* GetActiveView1();          //PROTOTYPE
       CAGNTView* pView=GetActiveView1();



       pView->ThreadData.iPlaneIndex=m_iCurrentLevel;
       pView->Invalidate();
        ............
}
```

Script 32: Modifications in the function CAGNTView::OnPaint()

B5.3 Painting the agents in draft in a plane

The next function `CBackground::InvertObjects_3D` (in the file Background.cpp) paints the agents generated by the function `CBackground::FillOusideObjects_3D`. in the plane selected by the plane selection dialog box.

```
void CBackground::InvertObjects_3D(CDC* pDC,
                       RECT rect,              //PARENT RECTANGLE
                             int  XDim,              //PLAYGROUND X DIMENSION
                       int  YDim,              //PLAYGROUND Y DIMENSION
                       int ZDim,
                       short iPlaneIndex,
                       short iWhichPlane2D,
                       COLORREF* color)
////////////////////////////////////////////////////////////////////////////
//HISTORY: VERSION 1.0 MAY 2009, BY J JWOJCIECHOWSKI
//3D SLICES XY,XZ,ZY PAINTING IN 2D PLAIN DRAFT
////////////////////////////////////////////////////////////////////////////
{
       ..............
       ..............
→    if(iWhichPlane2D==0){//XY
→            dLevel=((1.0*IPlaneIndex-1)/ZDim);
              if(AgentCell[i][j].z==dLevel)
                ..............
→               }else if(iWhichPlane2D==1){//XZ
                if(b_show_alllayers==true){
                 Arect.left=   Round(XFactor*AgentCell[i][j].x)-AgentSize/2;
                   Arect.top=    Round(YFactor*AgentCell[i][j].y)-AgentSize/2;
                   Arect.right=  Round(XFactor*AgentCell[i][j].x)+
                                   AgentSize/2+AgentSize%2;
                Arect.bottom= Round(YFactor*AgentCell[i][j].y)+
```

```
                AgentSize/2+AgentSize%2;
                pDC->Rectangle(&Arect);
              itmpNb++;
          }else{
                  .................
→                 dLevel=((1.0*IPlaneIndex-1)/YDim);
                  if(AgentCell[i][j].y==dLevel){
                  .................
→             }else if(iWhichPlane2D==2){//ZY
                  .................
→                 dLevel=((1.0*IPlaneIndex-1)/XDim);
                  if(AgentCell[i][j].x==dLevel) {
                  Arect.left=Round(XFactor*AgentCell[i][j].z)-AgentSize/2;
                  Arect.top= Round(YFactor*AgentCell[i][j].y)-AgentSize/2;

  Arect.right=Round(XFactor*AgentCell[i][j].z)+AgentSize/2+AgentSize%2;
                  Arect.bottom=
Round(YFactor*AgentCell[i][j].y)+AgentSize/2+AgentSize%2;
                  pDC->Rectangle(&Arect);// ←PAINTING FUNCTION
              }
              .................
              .................
```

Script 33: Modifications in the function CBackground::InvertObjects_3D

C Changes to paint agents during simulations

Painting periodically the agents is also necessary during a simulation. However, agents are no more painted by the `CXDraft` class. When the user starts a simulation (for instance when he (she) clicks the button RUN in the bottom toolbar of MASS application window), the function `void InitAgentFromDraft` displayed below converts the relative position of agents defined in the `CXDraft` class to absolute coordinates in the terrain. New code needed for the `Z` dimension is highlighted with grey background.

```
void InitAgentFromDraft_3D(CELL*  Cell,short  XDim,short  YDim, short ZDim,
              AGENT* Agent[AGENTTYPENB],short iInitNb[AGENTTYPENB],
              short iMaxNb[AGENTTYPENB],
              CXDraft* pTWnd)
////////////////////////////////////////////////////////////////////////////////
////
//
//     HISTORY: Version 1: MAY 2009, AUTHOR: Jarek Wojciechowski
////////////////////////////////////////////////////////////////////////////////
////
{
   //::MessageBox(NULL,"OK HERE","",MB_OK);
       int i=0, j=0, k=0, iSHIFT=0;
       int iANb=0;
       int XCoord, YCoord,ZCoord;
       for (i=0;i<AGENTTYPENB;i++) {
              iSHIFT=0;
        /////////////////3D
              for (k=0;k<pTWnd->m_Background.iAgentNb[i];k++) {
//SCAN ALL POINTS IN BACKGROUND
                     XCoord= (int) (XDim*pTWnd->m_Background.AgentCell[i][k].x);
                     YCoord= (int) (YDim*pTWnd->m_Background.AgentCell[i][k].y);
```

```
            ZCoord= (int) (ZDim*pTWnd->m_Background.AgentCell[i][k].z);

                        //REMEMBER THAT IN THE ASCII TABLE CHAR(49)='1'
                        Cell[ZCoord*XDim*YDim+XCoord*YDim+YCoord].State[0]=CHAR(49+i);
                        Cell[ZCoord*XDim*YDim+XCoord*YDim+YCoord].iRank=iSHIFT;
                        Agent[i][iSHIFT].X=XCoord;
                        Agent[i][iSHIFT].Y=YCoord;
            Agent[i][iSHIFT].Z=ZCoord;

                        Agent[i][iSHIFT].AgentMode='A';

        ////////////////////////////////////////////////////////////////////////
                        //DEFINE INITIAL AGENT MOVE DIRECTION
        →       Agent[i][iSHIFT].ShiftX[0]=rand()%3-1;
        →       Agent[i][iSHIFT].ShiftY[0]=rand()%3-1;
        →       Agent[i][iSHIFT].ShiftZ[0]=rand()%3-1;

        ////////////////////////////////////////////////////////////////////////
                        iSHIFT=iSHIFT+1;
                }

////////////////////////////////////////////////////////////////////////////////
                //      INITIALIZATION OF INACTIVE AGENTS IF iInitNb<iMaxNb. A SIMPLE
TRICK TO
                //      INITIALIZE THE WHOLE ARRAY
                for (j=iInitNb[i];j<iMaxNb[i];j++) {
                        Agent[i][j].X=0;
                        Agent[i][j].Y=0;
            Agent[i][j].Z=0;


                        Agent[i][j].AgentMode='D';
                }

////////////////////////////////////////////////////////////////////////////////
        }
}
```

Script 34: Modifications in the function `InitAgentFromDraft()`

Painting of the terrain is executed periodically by the member function `CAGNTView::OnPaint()`. As shown below, we integrated in this function a branch to separate the new 3D code from the existing one to preserve the ascending compatibility and to make that any hypothetical fault in the new code could no perturbate the operation of MASS for 2D applications.

```
void CAGNTView::OnPaint(){
        .................
        //code ajoute par JWOJCIECHOWSKI

         CAGNTView* GetActiveView1();        //PROTOTYPE
         CAGNTView* pView=GetActiveView1();
                if(pView->ThreadData.ZDim==1){
                        DrawAgents(&dc1,1);
                }else if (pView->ThreadData.ZDim>1){
→                       DrawAgents_3D(&dc1,1);
                }
        .................
}
```

Script 35: Modifications in the function `CAGNTView::OnPaint()`

The code shows that 3D painting of agents at runtime is executed by the function `CAGNTView::DrawAgents_3D`. We follow the approach already described in section B.5 page 178 for painting the agent populations when a scenario is selected. Consequently, we paint the agents located in a plane, possibly a `XY or YZ` or `ZX` plane. In all cases, we must define the plane index `iLevel`, i.e., the coordinate in the direction perpendicular to the plane.

- The `iLevel` variable selects the agent to be painted from appropriate level. It addresses the integer coordinates. `iLevel` is decreased by one to address the agents in array indexed started with 0 to less than XDIM or YDIM or ZDIM. `ThreadData.iWhichPlane2D` variable selects the appropriate plain to be painted. The value is set to 0,1 or 2 respectively of XY,XZ,ZY plain.
- `ThreadData.iPlaneIndex` and `ThreadData.iWhichPlane2D` are changed by controls of CDlg3DBox dialog described in D.2.

```
void CAGNTView::DrawAgents_3D(CDC* dc, int iter)
   …
            ////////////////////////////////////////////////////////////////////////////////
//
            //DRAW NEW POSITION
→   int iLevel=ThreadData.iPlaneIndex-1;
    bool b_show_alllayers=ThreadData.b_show_alllayers;
            …
            dc->SelectObject(APen);
            //code to paint the slices in XZ and ZY plains
→   if(ThreadData.iWhichPlane2D==0){//XY
            Xpos=Round(1.0*ThreadData.Agent[i][j].X*(rect.right-rect.left)/(ThreadData.XDim-
1));
            Ypos=Round(1.0*ThreadData.Agent[i][j].Y*(rect.bottom-rect.top)/(ThreadData.YDim-
1));
            Zpos=Round(1.0*ThreadData.Agent[i][j].Z);
            //*(rect.bottom-rect.top)/(ThreadData.ZDim-1));
            if(b_show_alllayers==true){//PAINTING ALL 3D AGENTS IN PLAIN
             DrawShape(dc,ThreadData.Agent[i][j].iShape,Xpos,Ypos,iRectSide);
             itmpNb++;
            }else{
            if(Zpos==iLevel){
             DrawShape(dc,ThreadData.Agent[i][j].iShape,Xpos,Ypos,iRectSide);
               …
            }
            }
→           }else if(ThreadData.iWhichPlane2D==1){//XZ
            Xpos=Round(1.0*ThreadData.Agent[i][j].X*(rect.right-rect.left)/(ThreadData.XDim-
1));
            Ypos=Round(1.0*ThreadData.Agent[i][j].Y);
            Zpos=Round(1.0*ThreadData.Agent[i][j].Z*(rect.bottom-rect.top)/(ThreadData.ZDim-
1));
            if(b_show_alllayers==true){
             DrawShape(dc,ThreadData.Agent[i][j].iShape,Xpos,Zpos,iRectSide);
             itmpNb++;
            }else{
→           if(Ypos==iLevel){
            DrawShape(dc,ThreadData.Agent[i][j].iShape,Xpos,Zpos,iRectSide);
            …
            }
            }
→           }else if(ThreadData.iWhichPlane2D==2){//ZY
            Xpos=Round(1.0*ThreadData.Agent[i][j].X)*1;//;
```

```
            Ypos=Round(1.0*ThreadData.Agent[i][j].Y*(rect.bottom-rect.top)/(ThreadData.YDim-
1));
            Zpos=Round(1.0*ThreadData.Agent[i][j].Z*(rect.right-rect.left)/(ThreadData.ZDim-
1));
            if(b_show_alllayers==true){
             DrawShape(dc,ThreadData.Agent[i][j].iShape,Zpos,Ypos,iRectSide);
             itmpNb++;
            }else{
→           if(Xpos==iLevel){
            DrawShape(dc,ThreadData.Agent[i][j].iShape,Zpos,Ypos,iRectSide);
            …
            }
            }
   }delete ABrush;delete APen;
   }
   }
   ////////////////////////////
    //WORKING, CORRECT CODE TO PAINT HIDDEN OBSTACLES AROUND THE 3D PLAYGROUND
    //USED ONLY FOR TESTING THE MEMORY
            CBrush* ABrush = new CBrush(RGB(0,0,0));     //PROVISORY COLOR FOR BLACK
    OBSTACLES
            CPen* penCur = new CPen(PS_NULL,1,RGB(0,0,0));
            dc->SelectObject(ABrush);
            dc->SelectObject(penCur);
            dc->SetROP2(R2_NOTXORPEN);

             if(ThreadData.iWhichPlane2D==0){//XY
             //iLevel is for Z;
             int i;
                 if (ThreadData.bXtorusMode==false) for (i=0;i<ThreadData.XDim;i++)
            //ADD OBSTACLES TO BUILD THE BORDER
                 {
                  //Cell[iLevel*XDim*YDim+i*YDim].State[0]='O';
                 //Cell[iLevel*XDim*YDim+i*YDim+YDim-1].State[0]='O';
                  //checking only Y always 0 or max
                  char EndState=ThreadData.Cell[(iLevel)*ThreadData.XDim*ThreadData.YDim
                                        +i*ThreadData.YDim
                                                    + 0].State[0];
                     if (EndState=='O') {
                     dc->Rectangle(
                             (i*(rect.right-rect.left)/(ThreadData.XDim-1))-iRectSide/2,
                             0-iRectSide/2,
                        (i*(rect.right-rect.left)/(ThreadData.XDim-
    1))+iRectSide/2+iRectSide%2,
                             0+iRectSide/2+iRectSide%2);
                  }

                     EndState=ThreadData.Cell[(iLevel)*ThreadData.XDim*ThreadData.YDim
                                        +i*ThreadData.YDim
                                         + ThreadData.YDim-1].State[0];
                     if (EndState=='O') {
                     dc->Rectangle(
                     (i*(rect.right-rect.left)/(ThreadData.XDim-1))-iRectSide/2,
                     ((ThreadData.YDim-1)*(rect.bottom-rect.top)/(ThreadData.YDim-1))-
    iRectSide/2,
                        (i*(rect.right-rect.left)/(ThreadData.XDim-
                    1))+iRectSide/2+iRectSide%2,
                     ((ThreadData.YDim-1)*(rect.bottom-rect.top)/
                     (ThreadData.YDim-1))+iRectSide/2+iRectSide%2);
                  }
                 }
                 if (ThreadData.bYtorusMode==false) for (i=0;i<ThreadData.YDim;i++)
                    //ADD OBSTACLES TO BUILD THE BORDER
```

```
           {
            char
            EndState=ThreadData.Cell[(iLevel)*
                    ThreadData.XDim*ThreadData.YDim+ 0+ i].State[0];
                if (EndState=='O') {
                dc->Rectangle(
                        0-iRectSide/2,
                        (i*(rect.right-rect.left)/(ThreadData.YDim-1))-iRectSide/2,
                        0+iRectSide/2+iRectSide%2,
                        (i*(rect.right-rect.left)/
                    (ThreadData.YDim-1))+iRectSide/2+iRectSide%2);
                    }

                EndState=ThreadData.Cell[(iLevel)*ThreadData.XDim*ThreadData.YDim
                                +(ThreadData.XDim-1)*ThreadData.YDim+i].State[0];
                if (EndState=='O') {

                 dc->Rectangle(
                        ((ThreadData.XDim-1)*(rect.right-rect.left)/
                             (ThreadData.XDim-1))-iRectSide/2,
                        (i*(rect.right-rect.left)/(ThreadData.YDim-1))-iRectSide/2,
                        ((ThreadData.XDim-1)*(rect.right-rect.left)/
                             (ThreadData.XDim-1))+iRectSide/2+iRectSide%2,
                        (i*(rect.right-rect.left)/
                             (ThreadData.YDim-1))+iRectSide/2+iRectSide%2
                        );
              }
            }
        //if iLevel from Z MIN to MAX
          if (ThreadData.bZtorusMode==false) for (i=0;i<ThreadData.XDim;i++)
              //ADD OBSTACLES TO BUILD THE BORDER
           {
            for(int j=0;j<ThreadData.YDim;j++){
              // Cell[i*YDim+j].State[0]='O';//+j
                    // Cell[(ZDim-1)*XDim*YDim+i*YDim+j].State[0]='O';
               char EndState=ThreadData.Cell[(iLevel)*
              ThreadData.XDim*ThreadData.YDim+i*ThreadData.YDim +j].State[0];
               if (EndState=='O') {
               dc->Rectangle(
                        (i*(rect.right-rect.left)/(ThreadData.XDim-1))-iRectSide/2,
                        (j*(rect.right-rect.left)/(ThreadData.YDim-1))-iRectSide/2,
              (i*(rect.right-rect.left)/(ThreadData.XDim-
1))+iRectSide/2+iRectSide%2,
              (j*(rect.right-rect.left)/(ThreadData.YDim-
1))+iRectSide/2+iRectSide%2);
            }
            }
           }
     //  }//
        }//XY plain

delete ABrush;
delete penCur;
```

Script 36: Modifications in the function CAGNTView::DrawAgents_3D()

D Interface Changes

D.1 Modification to the parameter page

- The Z dimension of background space and Z torus mode may be changed with Menu->param dialog.
- Saving the settings to the registry is done in **`CParamSheet::OnStoreInRegistries`** - ParamSheet.cpp

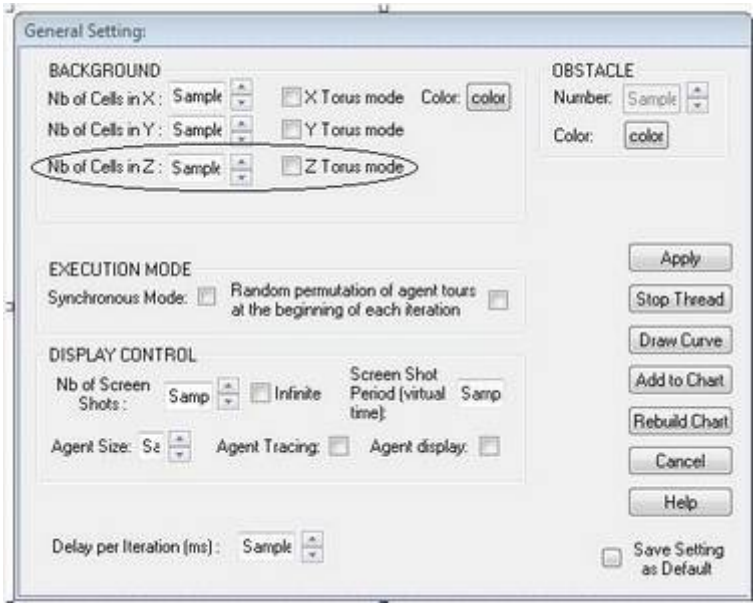


Fig. 64: Figure of param1 dialog graphics interface

```
LRESULT CParamSheet::OnStoreInRegistries(WPARAM wParam,LPARAM lParam)
{
    ............
    //STORE PAGE1 SETTINGS AS DEFAULT PARAMETERS
    AfxGetApp()->WriteProfileInt("PROP PAGE1","XDim",m_Page1.XDim);
    AfxGetApp()->WriteProfileInt("PROP PAGE1","YDim",m_Page1.YDim);
    AfxGetApp()->WriteProfileInt("PROP PAGE1","ZDim",m_Page1.ZDim);
    ...
→       if (m_Page1.bZTorusMode==TRUE)
              AfxGetApp()->WriteProfileInt("PROP PAGE1","bZTorusMode",1);
        else AfxGetApp()->WriteProfileInt("PROP PAGE1","bZTorusMode",0);
    ............
    etc ...
}
```

Script 37: Modifications in the function `CParamSheet::OnStoreInRegistries ()`

The changes to parameter page when the Dlg3DBox is open results in changing on line the Dlg3DBox controls what is presented in the code below.

```
void CParamSheet::TransferPage1ParametersToCOREDATA()
////////////////////////////////////////////////////////////////////////////////
////
//      AUTHOR: JHC
//      HISTORY: VERSION 1: JAN 2003
//                       2: JWOJCIECHOWSKI JUNE 2009
//
//      INFORMATION:
//  CODE WRITTEN TO BE AUTOSCALABLE VERSUS THE NUMBER OF AGENTS! THIS FUNCTION IS
CALLED
//  PRIO TO RUNNING A SIMULATION TO COPY THE AGENT PARAMETERS IN CParamSheet TO
//  CView.ThreadData
////////////////////////////////////////////////////////////////////////////////
////
{
        if (m_Page1.m_hWnd==NULL) return;
    ////////////////////////////////////////////////////////////////////
        int i,j,k;
        CAGNTView* GetActiveView1();         //PROTOTYPE
        CAGNTView* pView=GetActiveView1();
        COREDATA* pData=&pView->ThreadData;
    ////////////////////////////////////////////////////////////////////
        m_Page1.UpdateData(TRUE);
        pData->XDim=(short) m_Page1.XDim;
        pData->YDim=(short) m_Page1.YDim;
    pData->ZDim=(short) m_Page1.ZDim;

    //UPDATE OF m_pDlg3DBox IF IT IS AVAILABLE  OPEN
    if (pView != NULL ) {
         if(pView->m_pDlg3DBox!=NULL){
             CString tmp;
             tmp.Format("%d",pData->XDim);
             pView->m_pDlg3DBox->s_XDIM=tmp;
             tmp.Format("%d",pData->YDim);
             pView->m_pDlg3DBox->s_YDIM=tmp;
             tmp.Format("%d",pData->ZDim);
             pView->m_pDlg3DBox->s_ZDIM=tmp;

             int ioldpos=pView->m_pDlg3DBox->m_Spin1_current_level.GetPos();

             pView->m_pDlg3DBox->m_Spin1_current_level.SetDecimalPlaces (0);
                pView->m_pDlg3DBox->m_Spin1_current_level.SetTrimTrailingZeros
(FALSE);
                pView->m_pDlg3DBox->m_Spin1_current_level.SetRangeAndDelta (1,pData-
>ZDim,1);
             if(ioldpos<pData->ZDim)
             {
             pView->m_pDlg3DBox->m_Spin1_current_level.SetPos(ioldpos);
             }else{
             pView->m_pDlg3DBox->m_Spin1_current_level.SetPos(1);
             }

             pView->m_pDlg3DBox->UpdateData(0);
             pView->m_pDlg3DBox->Invalidate();
         }
    }

        //THE PLAYGROUND IS A RECTANGULAR ARRAY OF CELLS
        //GENERATION AND DEFAULT INTIALIZATION OF THE GRID. POSSIBLE STATES FOR CELL:

        // 'E': EMPTY, 'O': OBSTACLE, '1': AGENT OF TYPE 1, '2': AGENT OF TYPE 2
```

```
        delete [] pView->ThreadData.Cell;

    pData->Cell= new CELL[m_Page1.XDim*m_Page1.YDim*m_Page1.ZDim];

        int itmp=0;
        for (i=0;i<m_Page1.XDim;i++){
               for (j=0;j<m_Page1.YDim;j++){
               for (k=0;k<m_Page1.ZDim;k++){
                     pData-
>Cell[k*m_Page1.XDim*m_Page1.YDim+i*m_Page1.YDim+j].State[0]='E';
               itmp++;
            }}}
```

…

```
    ////////////////////////////////////////////////////////////////////////
       pData->ScreenShotPeriod=m_Page1.ScreenShotPeriod;
       m_bSynchronous=m_Page1.bSynchronous;
       pData->bSynchronous=m_bSynchronous;
    ////////////////////////////////////////////////////////////////////////
       }
```

Script 38: Modifications in the function **`CParamSheet::TransferPage1ParametersToCOREDATA`** ()

E Modifications of DLLs

E1.1 Modifications of skeleton methods of DLLs

There are 26 DLLs missions projects, the methods of which had been changed to meet the declared signature methods in Agent.h.

MASS VC9_3D_cvs\DLLs\
<DIR> A0 with Com
<DIR> Aym Default for A0
<DIR> Aym Default for A1, A2, A3
<DIR> Default for A0
<DIR> Default for A1, A2, A3
<DIR> FleeA_AttackB version1
<DIR> LifeGame
<DIR> Metastability1 for A0
<DIR> Minimum DLL
<DIR> Repeater02
<DIR> Repeater06
<DIR> Repeater21
<DIR> StayClose
<DIR> Terminal02
<DIR> Terminal06
<DIR> Terminal21

And the DLLs in tutorial directory:

VC9_3D_cvs\TUTORIAL DLLs\
<DIR> Energy for A0

<DIR> Energy for A0 with Com
<DIR> FleeA_AttackB version2
<DIR> Move Alone_1
<DIR> Repeater01
<DIR> Repulsive_0
<DIR> Repulsive_1
<DIR> Several Station For A2
<DIR> Station For A2
<DIR> Terminal01

E.1.1.1 Registering the mangled names for DLLs functions

In the file definition ".def" of each DLL there are registered mangled names for the member functions of the AGENT class. They are generated by the dumpbin.exe according to the procedure described in Appendix A1 of this manual.

Below are presented the signatures of the new 3D ready methods implemented by DLLs. It should be stressed that adding another variable to the skeleton methods implemented by DLLs one should comment the actual definition of the mangled name for the changed function, compile the DLL, execute the procedure described in Appendix A1, paste the new mangled name to the definition file and compile.

```
   DllBuildSE = ?BuildEnvACTION@AGENT@@QAEHPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44@Z
PRIVATE
   DllFindState = ?DllFindState@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAF_N33@Z   PRIVATE
   FineAgentScan =
?DllFINEAgentScan@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44@Z    PRIVATE
   CoarseCellScan  =
?DllCOARSECellScan@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44PAY01FFF@Z
PRIVATE
   CoarseAgentScan =
?DllCOARSEAgentScan@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44@Z   PRIVATE
   FineCellScanAction =
?ScanFINECellAction@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44FF@Z PRIVATE

   FineCellScanNode =
?ScanFINECellNode@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44FF@Z   PRIVATE

   DllBuildSE_NODE =
?BuildEnvNODE@AGENT@@QAEHPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44@Z   PRIVATE


   NodeScanOutBuf   = ?DllOutPolicy@NODE@@QAEXQAPAVAGENT@@QAFQAY04PAY03FQAY04F@Z
PRIVATE
```

Chapter 11

Chapter history:
Version 1.0, June 2008 by JHC

MASS deployment

This chapter describes the different operations necessary to generate the installation program deploying MASS on PCs at least operated under Win2000. We describe the utility `Deployer.exe`, which automates the procedure.

The deployment is the final phase of the development which consists in generating the application entitled `MASS_SetUp.exe`, which installs the file system to run `MASS.exe` and to develop additional DLLs. All files involved in the deployment phase are in the directory `MASS\INSTALLER` as shown in Fig. 1 page 13. The contents of this directory is represented in the next figure. Note that the final file `MASS_SetUp.exe` is in `MASS\INSTALLER\Output`.

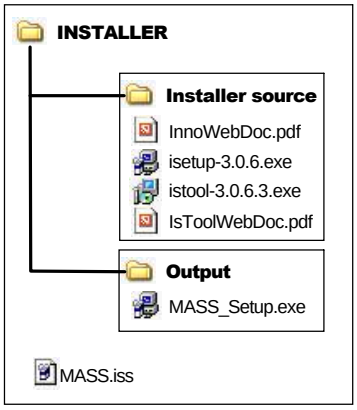


Fig. 65: Files and directories in the deployment procedure

The deployment of the application consists in writing a script compiled by Inno Setup, which is a *free* installer for Windows programs. The Script, entitled `MASS.iss`, is located in `MASS\INSTALLER`. Its development is greatly simplified with another freeware entitled IsTools. Both programs are stored in MASS\INSTALLER\Installer Source. However, the latest versions can be freely downloaded from the web sites: http://www.jrsoftware.org, and http://www.istool.org/. We assume in the following that both programs have been installed in the machine.

The procedure to create the final file `MASS_SetUp.exe` is a task, which is not complicated but long and tedious.

- Select a project a directory that contains a MASS project. For instance, let us assume for clarity that you selected the project in the directory `D:\Projects03\MASS\April03`.
- Copy all files of the selected project in the directory `D:\Projects\MASS\TEMP`. Remember that the project (including the `CORE` and all `DLLs`) is always developed in the Debug mode. Thus, it is safe to copy all project files in a new directory and to recompile it in the release mode. The development files are therefore not affected by the deployment process. Note that

the directory TEMP is deleted at the end of the cycle. All following operations are executed in the temporary directory TEMP.

- Recompile the core solution (`D:\Projects\MASS\TEMP\CORE\ Agnt.sln`) in the release mode
- Recompile all DLLs projects (in the directories `D:\Projects\MASS\ TEMP\DLLs` and `D:\Projects\MASS\TEMP\ TUTORIAL`) in the release mode.
- Copy all DLLs output files (i.e., `Default for A0.dll`, `Default for A1.dll`, …) in `D:\Projects\MASS\TEMP\CORE\ MissionLibrary`. (In principle this operation is automatically executed when recompiling the DLLs).
- Copy default DLLs in `D:\Projects\MASS\TEMP\CORE` (as `A0Mission.dll`, `A1Mission.dll`, …).
- Run Inno Setup to compiler the setup string `D:\Projects\MASS\ INSTALLER\MASS.iss`.
- Delete `D:\Projects\MASS\TEMP`.

The previous operations generate the installation file `D:\Projects\MASS\INSTALLER\Ouptput\MASS_Setup.exe`. We developed the small utility entitled `Deployer.exe` to automate all above operations.

A Deployer.exe

This application is located in . The frame window of Deployer.exe is shown in Fig. 66.

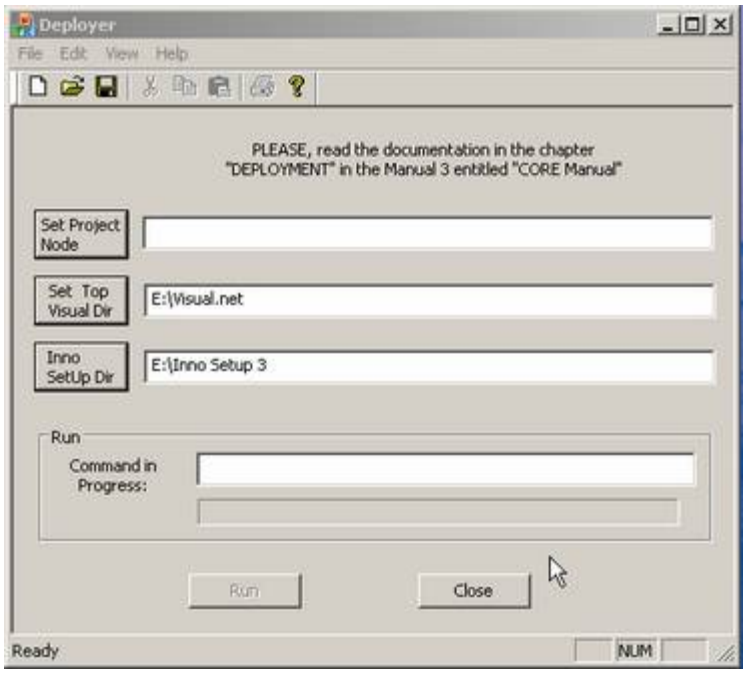


Fig. 66

3 directories must be selected to run the program, namely:

1) The directory, which contains the development project of MASS. In the previous discussion, we considered `D:\Projects03\MASS\April03`. To select the directory click the button `Set`

`Project Node`. This operation fires the new tree window represented in Fig. 67. Simply select the directory containing the project that must used to generate the SetUp application.

2) The directory, which contains the development environment Visual.net. Simply click the left button "Set Top Visual Dir" to select this directory. This selection will be saved in the system registries and loaded on startup for the next runs of the program.
3) The directory, which contains the compiler Inno Setup. Simply click the left button "Inno SetUp Dir" to select this directory. This selection will be saved in the system registries and loaded on startup for the next runs of the program.

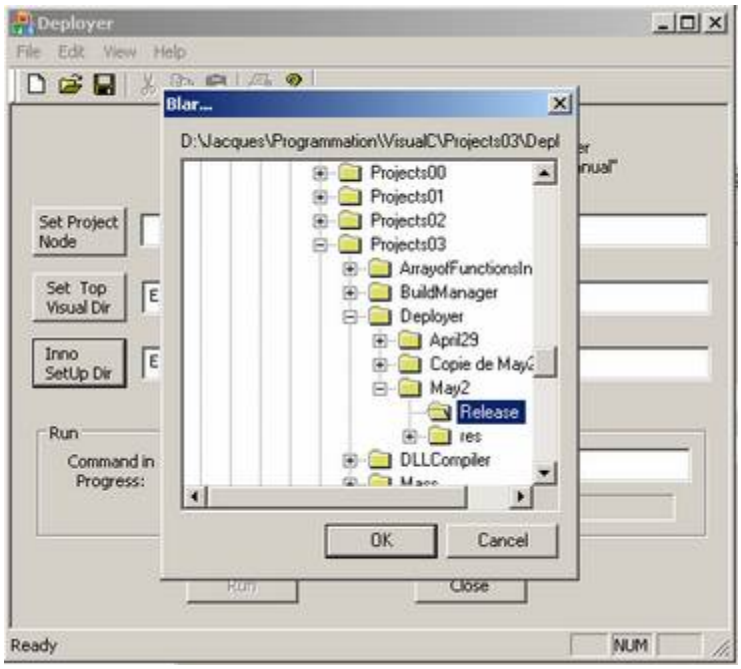


Fig. 67

Chapter 12

Framework for a new chapter

This chapter describes t…

The deployment is the final phase of the development which consists in generating the application entitled `MASS_SetUp.exe`, which installs the file system to run `MASS.exe` and to develop additional DLLs. All files involved in the deployment phase are in the directory `MASS\INSTALLER` as shown in Fig. 1 page 13. The contents of this directory is represented in the next figure. Note that the final file `MASS_SetUp.exe` is in `MASS\INSTALLER\Output`.

B Deterministic policies in the COARSE mode

B.1 Predator policies

B1.1 Policy0:

States in Policy0 are identical in the `FINE` and `COARSE` modes. They are described in the natural language in **Erreur ! Source du renvoi introuvable.**. Policy0 is a 3-State policy. The difference between **Erreur ! Source du renvoi introuvable.** and **Erreur ! Source du renvoi introuvable.** is that we do not use the same parameters to label the states.

State Identification	Signification
`State0`	No prey, no predator detected inside the sense radius
`State1`	No prey detected. Predators detected inside the sense radius
`State2`	On (or several) prey(s) detected inside the sense radius

Table 5: Set of States

The FINE and COARSE modes store differently the environment.

- The FINE mode stored the environment in the array FoundAgent[l][j][k] (see the declaration in the agent header).
- The COARSE mode stores the environment in the array `COARSE_ENVIRONMENT COARSEEnviron[ITERATNB]`(see the declaration in the agent header). The

The agent scans the surrounding cells and build a COARSE representation of the sectors in accordance with definition in paragraph A.1 page 127. **Erreur ! Source du renvoi introuvable.**-1 represents State0. **Erreur ! Source du renvoi introuvable.**-2 represents one example of state1.**Erreur ! Source du renvoi introuvable.** (from 3 to 6)

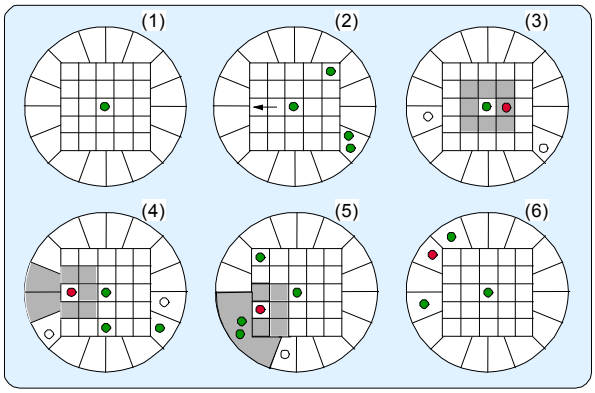


Fig. 68: Examples of states; Green circle: predator; Red circles: preys

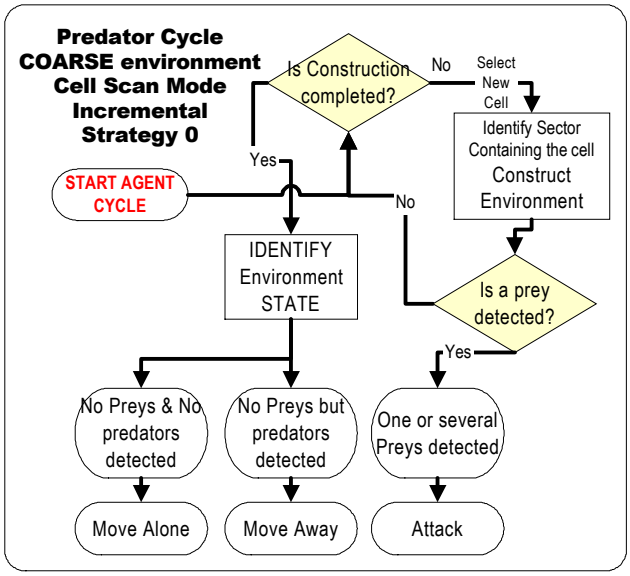


Fig. 69: Algorithm to construct the environment and choose a policy in the COARSE incremental mode, iPolicy0=0..

The execution is the following:

- `COARSECellRingScan0` identifies the sector that contains any new cell and checks whether a prey is identified. If it is, the construction is aborted and an “Attack” action is undertaken.

B1.2 Policy 1

The construction of the COARSE environment is incremental and uses the Cell Scan Mode (CSM). Each iteration, the member function `void AGENT::COARSECellScan0` executes the algorithm shown in **Erreur ! Source du renvoi introuvable.**.

The agent stops the incremental construction when it finds a prey (condition 1) and when there is no partner in the same far sector (condition 2).

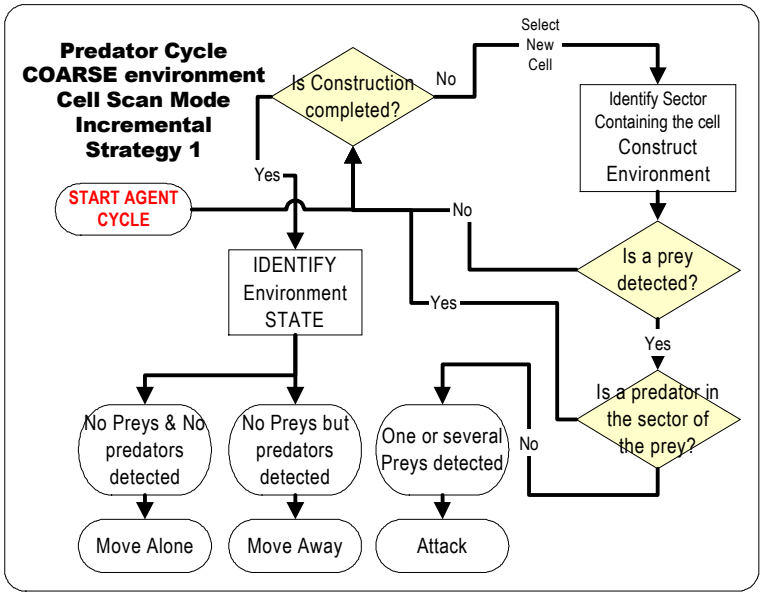
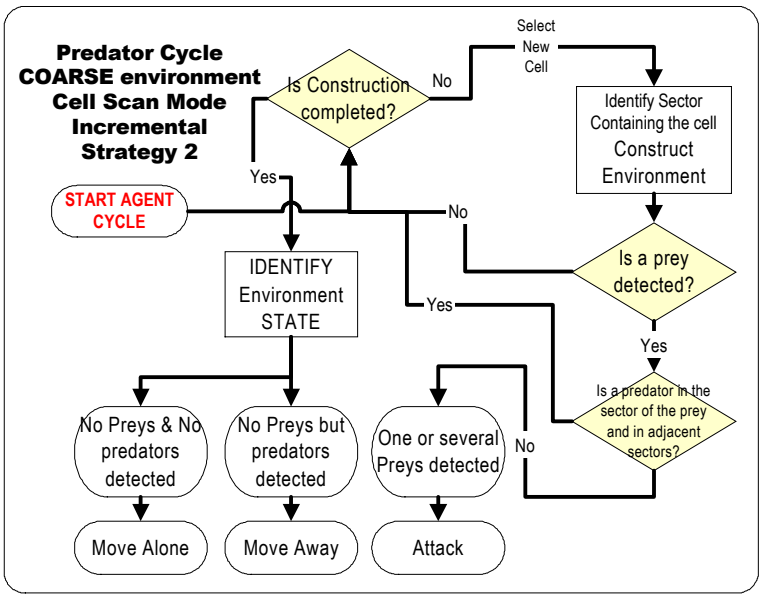


Fig. 70: Algorithm to construct the environment and choose a policy in the COARSE incremental mode, iPolicy0=1. Note the change with respect to **Erreur ! Source du renvoi introuvable.**.

B1.3 Policy 2

The agent stops the scan when it finds a prey (condition 1) and there it is no partner in the same far sector (condition 2) and no partner in adjacent sectors (condtion 3).Because of the incremental construction, condition 2 makes that the construction stops if there is no partner between the prey and the agent. Condition 3 makes that the construction is stopped is there is a partner closer in an adjacent sector.


Predator Cycle
COARSE environment
Cell Scan Mode
Incremental
Strategy 2
Is Construction completed?
No
Select New Cell
Identify Sector Containing the cell
Construct Environment
Yes
START AGENT CYCLE
No
Is a prey detected?
IDENTIFY Environment STATE
Yes
Yes
Is a predator in the sector of the prey and in adjacent sectors?
No Preys & No predators detected
No Preys but predators detected
One or several Preys detected
No
Move Alone
Move Away
Attack

A1

Appendix: Dynamic call of member functions in DLLs

History: New Version April 2012 JHC

We analyze in details an example to show how calling dynamically member functions in a DLL. Let us consider that we wish to export the member function int AGENT::MyFunc(int Par1) from a DLL. The function is it declared in the AGENT header as

```
__declspec(dllexport) int MyFunc(int Par1);
```

and implemented in the DLL code, for instance as:

```
__declspec(dllexport) int AGENT::MyFunc(int Par1)
{
      float provi=sin(Par1);
      return (int) 10*provi/(provi+1);
}
```

So far, so good. Now, how to call this member function in the client application? The natural method consist in loading the DLL and retrieving the function address. Let us assume that DLL3.dll has been selected. The **right** code could be similar to the following lines:

FIRST: ADD (ONE TIME) THIS BLOCK ANYWHERE IN THE CLIENT PROJECT:

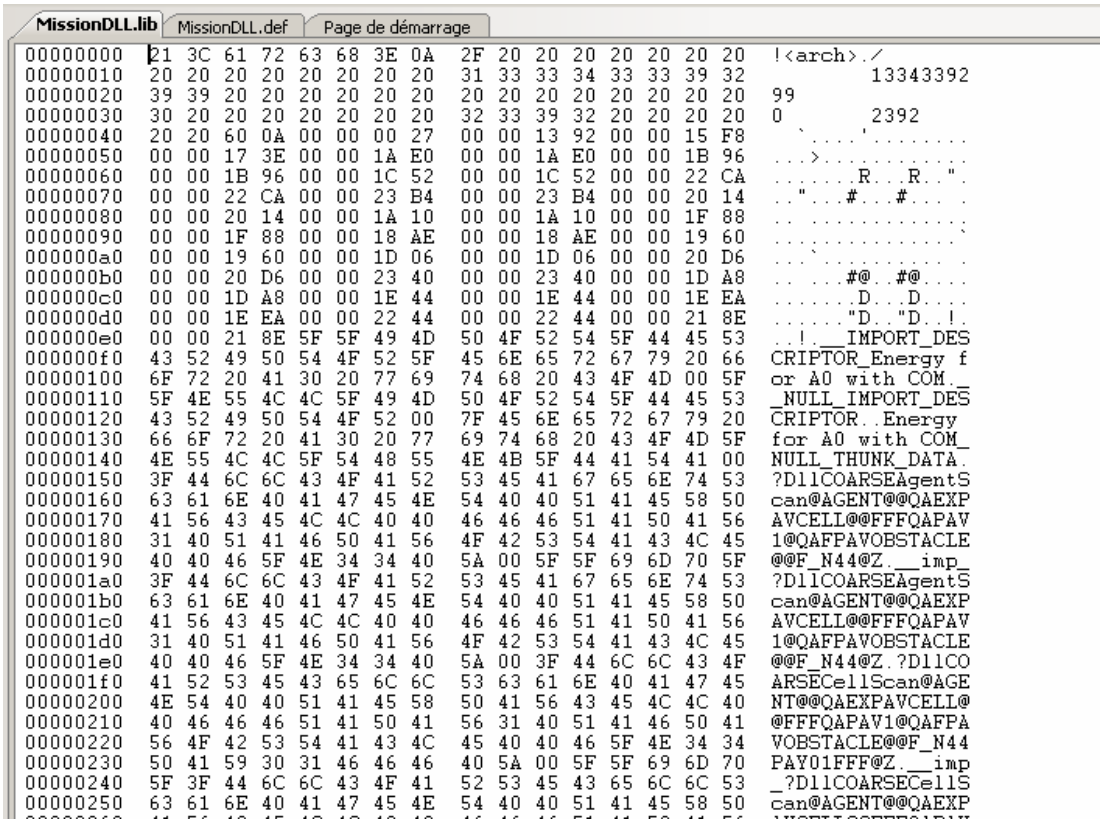
```
#ifndef _FORCECAST_H_
   #define _FORCECAST_H_
   template<class Dest, class Src>
   Dest force_cast(Src src)
   {
      union
      {
           Dest d;
           Src s;
      } c onvertor;
      convertor.s = src;
      return convertor.d;
   }
#endif //_FORCECAST_H_
```

SECOND: ADD THIS CODE IN THE CLIENT TO CALL THE MEMBER FUNCTION IN THE DLL

```
////////////////////////////////////////////////////////////////////////////
//LOAD THE DLL
HMODULE hm=LoadLibrary("DLL3.dll");
////////////////////////////////////////////////////////////////////////////
//DEFINE A FUNCTION POINTER TYPE TO POINT TO AGENT::MyFunc IN THE DLL
typedef int (AGENT::*PMYFUNC)(int);
//MAP THE POINTER TO void AGENT::MyFunc() IN DLL. USE MANGLE NAME IN DLLName.def
PMYFUNC pMapMyFunc = force_cast<PMYFUNC>
                     (GetProcAddress((HINSTANCE) hm,"MangleMyFunc"));
////////////////////////////////////////////////////////////////////////////
int iPar=3;                                    //FOR INSTANCE
((pAgent)->*pMapMyFunc)(iPar);   //EXECUTE THE FUNCTION IN THE DLL.WE WE ASSUME
                      //THAT pAgent IS A POINTER TO AN AGENT OBJECT
////////////////////////////////////////////////////////////////////////////
```

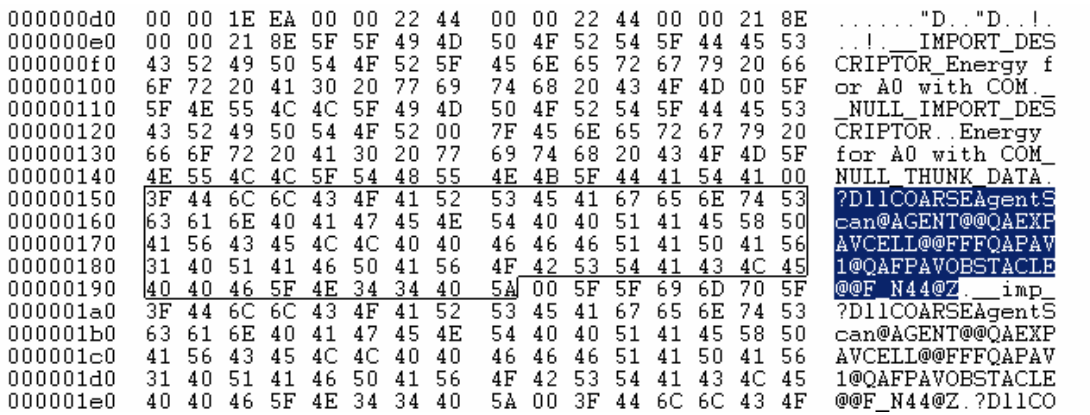
The trick here is that "MangleMyFunc" is NOT the name of the function in the DLL (in this example, it is MyFunc) but a friend name to replace the mangled name attributed by the compiler which is extremely long in general. It is mandatory because: 1) All C++ compilers change the function name in the DLL export table; 2) There is no standardization so that every compiler changes the name in a separate way. To replace the mangled name by a user-defined friend name with VisualC7, operate as follows:

1) Open the file MissionDLL.lib witn VisualC. If you compile in the DEBUG mode, this file is in the directory DEBUG of you DLL project. Thus with Visual Studio, move to this directory and double click the file MissionDLL.lib. Visual Studio should display this kind of file



The important column is the right most column. It contains the mangle names of the member functions of classes which are entry functions of the DLL. How to identify such mangle names. Simply, each one begins with and question mark!

Look at the highlighted text in the right most colum. It is explicitly:
?DllCOARSEAgentScan@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44@Z



```
000000d0  00 00 1E EA 00 00 22 44  00 00 22 44 00 00 21 8E  ......"D.."D..!.
000000e0  00 00 21 8E 5F 5F 49 4D  50 4F 52 54 5F 44 45 53  ..!.__IMPORT_DES
000000f0  43 52 49 50 54 4F 52 5F  45 6E 65 72 67 79 20 66  CRIPTOR_Energy f
00000100  6F 72 20 41 30 20 77 69  74 68 20 43 4F 4D 00 5F  or A0 with COM._
00000110  5F 4E 55 4C 4C 5F 49 4D  50 4F 52 54 5F 44 45 53  _NULL_IMPORT_DES
00000120  43 52 49 50 54 4F 52 00  7F 45 6E 65 72 67 79 20  CRIPTOR..Energy
00000130  66 6F 72 20 41 30 20 77  69 74 68 20 43 4F 4D 5F  for A0 with COM_
00000140  4E 55 4C 4C 5F 54 48 55  4E 4B 5F 44 41 54 41 00  NULL_THUNK_DATA.
00000150  3F 44 6C 6C 43 4F 41 52  53 45 41 67 65 6E 74 53  ?DllCOARSEAgentS
00000160  63 61 6E 40 41 47 45 4E  54 40 40 51 41 45 58 50  can@AGENT@@QAEXP
00000170  41 56 43 45 4C 4C 40 40  46 46 46 51 41 50 41 56  AVCELL@@FFFQAPAV
00000180  31 40 51 41 46 50 41 56  4F 42 53 54 41 43 4C 45  1@QAFPAVOBSTACLE
00000190  40 40 46 5F 4E 34 34 40  5A 00 5F 5F 69 6D 70 5F  @@F_N44@Z.__imp_
000001a0  3F 44 6C 6C 43 4F 41 52  53 45 41 67 65 6E 74 53  ?DllCOARSEAgentS
000001b0  63 61 6E 40 41 47 45 4E  54 40 40 51 41 45 58 50  can@AGENT@@QAEXP
000001c0  41 56 43 45 4C 4C 40 40  46 46 46 51 41 50 41 56  AVCELL@@FFFQAPAV
000001d0  31 40 51 41 46 50 41 56  4F 42 53 54 41 43 4C 45  1@QAFPAVOBSTACLE
000001e0  40 40 46 5F 4E 34 34 40  5A 00 3F 44 6C 6C 43 4F  @@F_N44@Z.?DllCO
```

It is the mangle name in the DLL of the member function: void AGENT::DllCOARSEAgentScan.
Thus in the file **MissionLIB.def**, there should be one line which refers to the mangle name to call this function, for instance:

CoarseAgentScan ?DllCOARSEAgentScan@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44@Z PRIVATE

THIRD: **It is YOUR RESPONSIBILITY TO ADD THIS LINE IN THE FILE MIssionLIB.def**! Here the mangle name (also called friend name) is CoarseAgentScan and it refers to the DLL function DllCOARSEAgentScan.

Similarily, the next mangle name in the DLL is:
DllCOARSECellScan@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44PAY01FFF@Z
It corresponds to the function void AGENT::DllCOARSECellScan
Thus in the file MissionLIB.def, there should be the line:
CoarseCellScan = ?DllCOARSECellScan@AGENT@@QAEXPAVCELL@@FFFQAPAV1@QAFPAVOBSTACLE@@F_N44PAY01FFF@Z PRIVATE

Here the mangle name is CoarseCelltScan

Another method

1. Change the working directory to `VisualStudio .NET\vc7\bin`.
2. Copy the file `DLL1.lib` in this directory that contains the tool `dumpbin.exe`.
3. Execute `vcvars32.bat` to allocate the paths needed to execute `dumpbin.exe`.
4. Execute the command line: `dumpbin.exe /ALL MissionDLL.lib`. The mangled names of the functions in the DLL are in the last part of the file generated by this instruction, in the EXPORT section. Let us assume for clarity that the mangled name is `?MyFunc@AGENT@@QAEXXZ`.
5. Once the mangled name of the function has been identified, you must modify the def file of the dll, (here `DLL1.def`), which is automatically generated by VisualC in the files of the DLL. In this example, we choose the friend name `MangleMyFunc` to replace real mangled name. Add the next red line

```
EXPORTS
    ; Explicit exports can go here
      MangleMyFunc = ?MyFunc@AGENT@@QAEXXZ       PRIVATE
```

6. Recompile the DLL

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